AD 731152

AGARD-R-586-71

AGARD-R-586-71

AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92 NEUILLY SUR SEINE FRANCE

AGARD REPORT No. 586

on

A Summary of Atmospheric Turbulence recorded by NATO Aircraft

by

Cyril G. Peckham

NORTH ATLANTIC TREATY ORGANIZATION

DISTRIBUTION AND AVAILABILITY
ON BACK COVER

134

AGARD Report 586

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

A SUMMARY OF ATMOSPHERIC TURBULENCE RECORDED BY NATO AIRCRAFT

by

Cyril G.Peckham

Technology Incorporated
Dayton, Ohio, USA

This report has been sponsored by the Working Group on Environmental Statistical Data of the AGARD Structures and Materials Panel.

THE MISSION OF AGARD

The mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community,

- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;

- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;

- Improving the co-operation among member nations in aerospace research and development;

- Exchanging of scientific and technical information;

- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;

- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each Member Nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Program and the Aerospace Applications Studies Program. The results of AGARD work are reported to the Member Nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The material in this publication has been reproduced directly from copy supplied by AGARD or the author.

Published September 1971

551.551.5

Printed by Technical Editing and Reproduction : d
Harford House, 7-9 Charlotte St, London. W1P 1 D

SUMMARY

This document describes 150,000 hours of turbulence data collected from seven participating NATO countries, the instruments used to measure the data, and the methods of processing the data and of separating the turbulence data from the maneuver data. In addition, it details the power spectral density methods used to derive gust velocities which are presented by altitude in Section 3. The original data as well as these gust velocities are presented in more detail in both magnetic tape files and in a voluminous summary report, copies of which have been sent to a representative in each of the participating countries. All work covered in this document was performed under Contract AGARD-OTAN SMP 67-68.

Ce document présente les données relatives à la turbulence atmosphérique recueillies par 7 nations partipantes dans le cadre de l'OTAN, ainsi que l'instrumentation utilisée pour effectuer les mesures requises, les méthodes de traitement des dites données et les critères de séparation entre les données relatives aux manoeuvres de l'avion et celles relatives à la turbulence.

De plus, les techniques de densité spectrale de puissance utilisées pour calculer les vitesses de rafale sont décrites en détail. La Section 3 présente les résultats de ce calcul sous forme de tables en fonction de l'altitude.

L'information originale ainsi que les vitesses de rafale sont présentées de facon plus détaillée sur bandes magnétiques et dans un rapport sommaire dont les copies ont été envoyées aux représentants de chaque nation participante. Le travail couvert par ce document a été effectué sous contrat AGARD-OTAN SMP 67-68.

FOREWORD

This report is the culmination of the first cooperative effort of the NATO nations, who both funded and otherwise supported the effort to collect the turbulence data described in AGARD Report 555. This data has now been preserved in a data base which has been distributed to the participating NATO nations.

Technology Incorporated is for the most part responsible for the success of this action.

G. COUPRY
Chairman,
AGARD Structures and Materials Panel
Working Group on Environmental
Statistical Data

CONTENTS

LIST OF FIGURES

LIST OF TABLES

A SUMMARY OF ATMOSPHERIC TURBULENCE RECORDED BY NATO AIRCRAFT

Cyril G. Peckham

INTRODUCTION

Until recently, for the design of an aircraft structure, the loads due to turbulence have been derived by assuming that gusts can be described as a sequence of discrete events. Amongst the deficiencies of this discrete gust approach are:

- Gusts in fact occur continuously when the aircraft is flying in turbulent air.
- Only a one-degree-of-freedom of movement (plunging) of the aircraft is considered.
- Gusts were assumed to have only one wave length; i.e., loads resulting from an excitation - due to gusts of the natural modes (dynamic response) of the structure - cannot be described adequately.

In order to overcome these deficiencies, the Structures and Materials Panel of AGARD (Advisory Group for Aerospace Research and Development) agreed with the suggestions of various experts from different NATO countries that both power spectral and extreme value methods should be applied to the measured response of operational aircraft to turbulent air.

A previous study (Reference 1) had shown that there were sufficient data distributed in the NATO countries that could be made available for this purpose. Accordingly, a committee was set up to work with a coordinator to both gather and reprocess these data. The committee consisted of Harry Hall and later Richard Sewell of Canada, Gabriel Coupry of France, Otto Buxbaum of Germany, Jack Burnham, A. J. Atkinson and later Norman Bullen of the U.K., William Austin and later Clem Schmid of the U.S. The countries who made their data available and provided funds to underwrite the project were Canada, France, Germany, Italy, the Netherlands, the United Kingdom, and the United States.

The funds were released through a contract between AGARD and Technology Incorporated of Dayton, Ohio, USA, which supplied the coordinator. The contract was initially monitored by William B. Miller and later by Col. Charles K. Grimes, both of Wright-Patterson AFB of the United States.

Initially, three types of data were sought. These were VGH data, extreme values occurring once per flight or flight segment, and true gust velocity data. The VGH data measured all vertical accelerations at the center of gravity along with the coincident values of airspeed and altitude. Either the extreme values were extracted from the VGH data or only the maximum and minimum gust accelerations in each flight or flight segments were read during the initial processing. The true gust velocity data were obtained from aircraft equipped with vanes or gust booms, and these aircraft were flown through patches of turbulence to obtain continuous gust data.

To meet the objectives of the AGARD work, the three coincident values of acceleration, airspeed, and altitude plus the coincident weight were required for the first two types of data. The data are not reported in this form; if this coincidence is preserved at all, it is preserved only at the site where the data were first processed. Here it exists in the form of computer listings, IBM cards, or reels of magnetic tapes. Thus, all data delivered under this project required additional effort on the part of persons at the source to make the data available. This additional effort was made willingly by the different participating countries.

Approximately 150,000 hours of VGH data were culled from the data made available. Of these hours, 76,000 could be used to generate the maximum and minimum gust accelerations for each flight.

The true gust velocity data were obtained from short-time measurements in continuous turbulence. The programs under which they were collected, as well as the information available, are described.

All of these data have been reported in three ways: this document designed for general distribution, two sets of magnetic tapes of five reels each which contain all of the original data as well as the calculated gust velocities and their modified frequency distributions, and a detailed summary data report. The last two forms of the data have a limited distribution but are available through selected representatives in each of the participating countries, each of whom has a complete set of data.

The last two forms of the data as well as the processing are discussed in the following sections, and the reasons for the limited distribution will become apparent when the sheer bulk of data and the number of persons who could use the data in these forms are considered.

SECTION 1

DATA AVAILABLE

The bulk of the VGH (airspeed, vertical acceleration, and altitude) data were recorded either on the RAE recorder or an oscillograph system. Brief descriptions of these and other systems, the methods of processing the data, and the means of separating the turbulence data from the maneuver data are given in Appendix A. More extensive treatments are given in Canadian, the United Kingdom, and the United States reports (References 19 and 23).

The VGH data were collected from operational aircraft, generally for the purpose of obtaining data for either damage calculations or design criteria. The processor, either subjectively or by the design of the instrument, set the thresholds for the vertical acceleration, separated the data into turbulence or maneuver categories, and counted the occurrences of accelerations in intervals. The threshold is that interval around the 1.0g line in which either measurements are not made or, if made, are not counted.

During the initial processing, additional parameters or constraints were added to the data. Among these were season, aircraft weight, fuel weight, mission segments (flight conditions), and flap position; but all of these were not common to all aircraft. Either parameters such as season and flight condition were coded directly, or a value was assigned to an interval and the interval was coded. Thus altitude code 1 could represent the interval of 0 to 1000 feet, vertical acceleration code 14 could represent the interval of 1.4g to 1.5g. Although the data from each flight were originally processed separately from all other flights, they must ultimately for statistical purposes be combined with the data from other flights. The individual flight data may or may not be preserved. In addition, the data might be preserved in the form of magnetic tapes, IBM cards, computer listings, etc. The coordinator received data from individual flights as well as combined data representing many flights and in all of the different forms. All in all, the coordinator received some 75 magnetic tapes of data, thousands of IBM cards, computer listings of data, and sundry small miscellaneous pages of data.

Some of the magnetic tapes contained data separated into maneuver and turbulence categories, the separation having already been made by the processor. Only the turbulence data were extracted from these tapes. For some flights in flight-by-flight data, the accelerations were processed only for certain mission phases such as low level. These flights were deleted in their entirety.

All of these magnetic tape data were written in different formats with different codes and intervals. Since one of the objectives of this program was to preserve the original data as far as possible, it was decided to rewrite all of the data in the same format but to preserve the original intervals wherever possible and to define the intervals for each set of data. However, some limit had to be set on the number of intervals for any parameter and this was chosen as twenty. In all but a few cases twenty was a safe limit. In the few cases where it was not, intervals in the original data were combined to reduce the number below 20. The only parameters affected were weight on one United States aircraft and airspeed and altitude on the U.K. data. The use of a single format required allocating space for each possible parameter. Thus, even though space has been left in the new format for all constraints, only those used by the original processor are entered. For any not used, the corresponding space is left blank. All data were kept separate by aircraft type and model. The preservation of the original intervals, and the variation in the number of constraints, require that the data for each aircraft type be preceded by a historical record defining these intervals and parameters. In each case the code identifies the interval or the lower limit of the interval.

The data received in tabular form, after keypunching, were combined with the other card data and written on tape. These tapes were then treated in the same manner as the tapes received originally.

VGH DATA FILES

After the VGH data were condensed, that is, similar data from different flights were combined, the accelerations were written as cumulative distributions - if they were not already in that form - for a given set of constraints, that is, constant values of weight, airspeed, altitude, season, etc. Any line in Figure 1-1 is one of these distributions and represents the data from many, many flights. During the processing two other forms of presentation were generated for each of these original distributions and inserted immediately following the appropriate original distribution. The first of these contained gust velocities in constant intervals - either 5 feet/second or 2 meters/second - with the original frequencies mathematically distributed over these intervals of gust velocity. These gust velocities are obtained by dividing Δn by $\bar{A}$, where Δn is the acceleration increment from the 1.0g condition, and $\bar{A}$ is the gust response function considering either the rigid or flexible response. The second inserted distribution modified the gust velocity distribution to remove the effect of the aircraft on the assumed spectrum of the atmosphere. These processing methods are discussed in detail in Section 2. To allow easy combination of the data, none of the

distributions in the files have been divided by the distance. This division must be performed prior to printing as was done in Figure 1-3. Any line in Figure 1-2 or 1-3 represents the first and second of these inserted distributions, respectively. The total number of nautical miles is carried in each one of these distributions.

All of the original VGH data plus the two added presentations for each were compacted to be stored on the minimal number of magnetic tapes. The set of data for each aircraft and model was preceded by a historical record describing the data stored for that aircraft.

C-130 E FLAPS RETRACTED

SEASON WINTER

W-H-V	TIME (HR)	DIST (NM)	-1.5	-1.0	-0.8	-0.6	-0.4	-0.3	-0.2	-0.1	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.5
			CUMULATIVE FREQUENCY OF DELTA-N (G'S)															
020102	0.66	83.						1	5	55	74	10	1					
020103	0.13	21.								14	10							
020104	0.07	16.						5	27	74	85	34	5	1				
020202	2.27	300.						1	22	276	358	56	12					
020203	0.62	101.					1	3	19	104	111	39	17	2				
020204	0.29	65.					5	26	117	327	357	120	22	3				
020205	0.00	1.								2	2	1						
020302	3.41	467.					1	9	93	665	761	142	39	6				
020303	2.45	406.					1	11	47	320	357	82	17	10				
020304	0.44	104.					5	17	75	229	233	90	31	7				
020305	0.15	40.						2	11	57	47	14	1					
020402	2.80	387.						7	60	525	637	108	24	2				
020403	2.84	487.					2	21	120	702	846	207	42	10				
020404	1.30	296.					12	33	192	616	644	200	45	10	1			
020405	0.16	43.						4	25	78	87	31	10	1				
020502	4.26	597.					2	7	61	575	579	78	11	4				
020503	8.97	1570.					5	35	153	1359	1435	258	48	7				
020504	3.60	834.					15	77	333	1242	1195	348	79	22	1			
020505	0.32	86.					4	7	19	78	72	24	7					
020602	0.27	42.					1	1	3	18	29							
020603	1.09	205.					2	7	27	117	138	43	4					
020604	0.70	175.					1	3	15	64	61	9						
020605	0.28	78.							12	47	38	8	2	1				
020702	0.04	6.																
020703	0.64	123.						3	9	36	44	6	2	1				
020704	0.57	148.					1	1	4	27	40	6	2					
020705	0.84	237.					1	3	5	8	13	5	2					
020802	0.07	12.																
020803	0.45	95.								9	6	1						
020804	0.59	158.							2	12	16	5	3	1				
020805	0.32	95.							4	15	15	3						
020902	0.57	93.																
020903	0.71	154.								13	1							
020904	0.85	240.							2	19	20	6	2	2				
020905	1.67	517.							2	17	19	2	1	1				
021002	0.48	83.																
021003	2.80	646.							1	14	22							
021004	3.82	1090.							4	23	19	2						
021005	0.14	45.								4	4	1	1					
021102	0.07	15.							2	9	12	2	2					
021103	2.58	608.							13	81	79	15	2	1				
021104	4.77	1504.						2	7	37	39	4	1	1				
021203	0.01	3.								5	7	1						
021204	0.66	214.						3	19	104	103	12	1					
030102	3.83	500.							32	255	329	53	9					
030103	2.01	333.						4	27	224	345	73	14	3				
030104	1.78	410.					19	55	203	795	965	356	92	18	1			
030202	8.71	1176.						20	175	1099	1292	210	35	3	1			
030203	5.74	966.					2	15	107	698	681	238	56	12				
030204	4.09	953.				2	35	173	666	2425	2525	799	225	41	1			

Figure 1-1. Original Data

SAMPLES OF THE DATA

Samples of the two generated distributions previously discussed are shown in Figures 1-2 and 1-3, and a sample historical record is shown in Figure 1-4. The distributions have been listed with headings and spaced for legibility, and each figure illustrates only one distribution type with each printed line corresponding to one distribution. Note that the constraints appear in the first column and in the heading of each table. Since the frequencies (number of occurrences) from the original data were mathematically distributed over the gust velocity ranges, there was no need to maintain them as integers. They are in all cases carried as decimals but are rounded to integers for the presentation of the cumulative gust frequency. Decimals less than 0.5 correspond to blanks in Figures 1-2 and 1-3, and also explain why Figure 1-3 may have an entry but Figure 1-2 has a blank in the corresponding position. The first frequency in line 020502 illustrates this. The blank in Figure 1-2 indicates the frequency is less than 0.5, but multiplication by $N_0(IN)/N_0(OUT)$ makes the frequency greater than 0.5.

The interpolation routine uses an exponential fit to two consecutive points of the original data and interpolates for the frequencies corresponding to 5,10,15,.... ft/sec, that occur in the interval bounded by the two points. Frequencies are not extrapolated, so that no frequencies are calculated for gust values less than the first observed value. The zero frequency after the last non-zero frequency is replaced by 0.1 and the interpolation carried out between the first observed value and the last. For example

if the first and last (frequency of 0.1) Δn give $\Delta n/\bar{A}$ values of 6.7 and 40.1, then frequencies are computed for $\Delta n/\bar{A}$ values of 10,15,20,....40.

C-130 E FLAPS RETRACTED

SEASON WINTER

W-M-V	TIME (HR)	DIST (NM)	CUMULATIVE GUST FREQUENCY OF DELTA-N/ABAR (FT/S)															
			-40.	-35.	-30.	-25.	-20.	-15.	-10.	- 5.	5.	10.	15.	20.	25.	30.	35.	40.
020102	0.66	83.						1	7			13	2					
020103	0.1?	21.								5	3							
020104	0.07	16.							1	36	44	2						
020202	2.27	300.						4	43			93	21	2				
020203	0.62	101.						1	8	72	86	27	4					
020204	0.29	65.						1	19	176	187	19	1					
020205	0.00	1.									1							
020302	3.41	467.				2	9	49	251			332	103	40	9	2		
020303	2.45	406.						8	42	301	340	73	15	7				
020304	0.44	104.						4	24	149	161	39	5					
020305	0.15	40.							1	20	22							
020402	2.80	387.				1	11	91	231			321	99	35	8	1		
020403	2.84	487.					3	27	149			240	94	13	8			
020404	1.30	296.					2	14	73	448	469	89	12	3				
020405	0.16	43.							4	43	52	10						
020502	4.26	597.			1	4	12	54	252			274	71	18	7	3	1	
020503	8.97	1570.				1	8	48	249			324	67	11	2			
020504	3.60	834.					2	22	158	878	868	164	30	4				
020505	0.32	86.						2	7	40	42	7						
020602	0.27	42.			1	1	1	3	9			6						
020603	1.09	205.					3	9	30			51	7					
020604	0.70	175.						1	6	43	35	2						
02060?	0.28	78.								26	18	2						
020702	0.04	6.																
020703	0.64	123.						4	11			9	2	1				
020704	0.57	148.						1	2	18	26	3						
020705	0.84	237.							3	6	9	2						
020802	0.07	12.																
020803	0.45	95.										1						
020804	0.59	158.								8	13	4	1					
020805	0.32	95.								9	9							
020902	0.57	93.																
020903	0.71	194.																
020904	0.85	240.							1	14	17	4	2					
020905	1.67	517.								10	11	1	1					
021002	0.48	83.																
021003	2.80	646.							2			1						
021004	3.82	1080.							2	20	16	1						
021005	0.14	45.								1	2	1						
021102	0.07	15.					1	3	7			9	3	2	2			
021103	2.58	608.						3	29			31	7	1	1			
021104	4.77	1504.						2	7			4	1	1				
021203	0.01	3.										2						
021204	0.66	214.						4	25			17	1					
030102	3.83	500.						2	56			87	19	2				
030103	2.01	333.							12	146	254	37	5	1				
030104	1.78	410.						3	43	340	526	64	5					
030202	8.71	1176.					7	69	356			421	95	20	2	1	1	
030203	5.74	966.					1	7	65	557	751	168	32	5	1			

Figure 1-2. Cumulative Gust Velocity Distribution

C-130 E FLAPS RETRACTED

SEASON WINTER

W-M-V	TIME (HR)	DIST (NM)	CUMULATIVE GUST FREQUENCY X NO(IN)/NO(OUT) OF DELTA-N/ABAR (FT/S)															
			-40.	-35.	-30.	-25.	-20.	-15.	-10.	- 5.	5.	10.	15.	20.	25.	30.	35.	40.
020102	0.66	83.						1	6			12	1					
020103	0.13	21.								4	3							
020104	0.07	16.								33	41	2						
020202	2.27	300.						4	45			96	22	2				
020203	0.62	101.						1	8	75	90	28	4					
020204	0.29	65.						1	20	187	198	16	1					
020205	0.00	1.									1							
020302	3.41	467.				2	11	59	302			399	124	48	11	3	1	
020303	2.45	406.					1	10	51	366	413	89	19	9	1			
020304	0.44	104.						5	30	186	201	49	7					
020305	0.15	40.							1	24	27							
020402	2.80	387.				2	15	69	308			428	131	46	11	2	1	
020403	2.84	487.				1	4	36	195			322	72	18	4	1		
020404	1.30	296.					3	20	100	611	640	122	17	4				
020405	0.16	43.							5	58	70	13						
020502	4.26	597.		1	2	5	18	81	375			408	106	27	10	5	2	1
020503	8.97	1570.				2	13	72	375			486	100	16	4	1		
020504	3.60	834.					3	35	241	1341	1327	251	46	7	1			
020505	0.32	86.						3	11	61	64	11						
020602	0.27	42.			1	1	2	4	13			9						
020603	1.09	205.				1	6	14	50			77	11					
020604	0.70	175.						2	9	66	52	3						
020605	0.28	78.								39	28	3	1					
020702	0.04	6.																
020703	0.64	123.						6	17			13	4	1				
020704	0.57	148.						1	3	28	40	5						
020705	0.84	237.						1	5	10	13	3						
020802	0.07	12.																
020803	0.45	95.										2						
020804	0.59	158.							1	13	19	6	2					
020805	0.32	95.								14	13							
020902	0.57	93.																
020903	0.71	194.							1									
020904	0.85	240.							1	21	25	6	2	1				
020905	1.67	517.							1	14	16	4	1					
021002	0.48	83.																
021003	2.80	646.							3			2						
021004	3.82	1080.							3	29	23	2						
021005	0.14	45.								1	3	1						
021102	0.07	15.					1	4	10			13	4	2	2	1		
021103	2.58	608.						4	40			43	10	2	1			
021104	4.77	1504.						3	10			6	1	1				
021203	0.01	3.							1			3						
021204	0.66	214.						6	33			23	2					
030102	3.83	500.						2	48			75	16	1				
030103	2.01	333.							10	127	221	32	5	1				
030104	1.78	410.						2	37	299	463	56	4					
030202	8.71	1176.					7	67	349			412	93	19	2	1	1	
030203	5.74	966.						7	64	550	741	165	31	5	1			

Figure 1-3. Modified Gust Frequency

AIRCRAFT TYPE	C-130, MODELS B AND E
COUNTRY OF ORIGIN	UNITED STATES OF AMERICA
TOTAL TIME	7650 HOURS
TOTAL DISTANCE	1851200 NAUTICAL MILES
GEOGRAPHY	SOUTH-EAST ASIA
INSTRUMENTATION	OSCILLOGRAPH
COUNTING METHOD	PRIMARY PEAKS
SYSTEM OF UNITS	FOOT-POUND-SECOND
DATE OF COLLECTION	1964-1969
ABARS AND NZEROS	FROM LOCKHEED (8 D.O.F.), CHECKED AT LOW LEVEL
EXTREME VALUES	AVAILABLE FOR ALL FLIGHTS
FLAPS POSITION	1= FLAPS EXTENDED, 0= FLAPS RETRACTED

RANGES OF VALUES	ACCELERATION (G)	AIRSPEED (KEAS)	ALTITUDE (FT)	WEIGHT (LB)	FUEL (LB)
1		LESS	0	73000	0
2		100	500	85000	5000
3	LESS	150	1000	95000	10000
4	-0.5 - 0.0	200	1500	105000	15000
5	0.0 - 0.2	250	2000	115000	20000
6	0.2 - 0.4	300	4000	125000	30000
7	0.4 - 0.6	350	6000	135000	40000
8	0.6 - 0.7		8000	145000	50000
9	0.7 - 0.8		10000	155000	60000
10	0.8 - 0.9		15000	165000	
11	1.1 - 1.2		20000	175000	
12	1.2 - 1.3		25000		
13	1.3 - 1.4		30000		
14	1.4 - 1.6				
15	1.6 - 1.8				
16	1.8 - 2.0				
17	2.0 - 2.5				
18	2.5 - 3.0				
19	MORE				

FLIGHTS SEGMENTS

1. INITIAL ASCENT
2. OTHER ASCENT
3. FIRST CRUISE
4. OTHER CRUISE
5. OTHER DESCENT
6. FINAL DESCENT TO LANDING
7. LOW LEVEL NAVIGATION
8. LOW LEVEL PRIOR TO AIRDROP
9. AIRDROP
10. LOW LEVEL POSTERIOR TO AIRDROP
11. PRACTICE LANDING
19. ASSAULT LANDING

Figure 1-4. Historical Record

Since not all countries use the same units, tapes using both the English and the International (SI) units were prepared. The original data were not changed; the only records affected are the distributions of gust velocities and the modified frequency distributions. The data in both units were not combined onto a single set of tapes since the computer time for any future work would be increased.

The units used to measure the various parameters in both systems are defined below.

Parameter	English	International
Weight	Pounds	Kilograms
Altitude	Feet	Meters
Airspeed	Knots	Knots
Acceleration	g's	g's
Gust Velocity	Feet/Second (interval- 5 ft/sec)	Meters/Second (interval- 2 meters/sec)

EXTREME VALUE FILES

Wherever individual flights were available, the maximum and minimum accelerations due to turbulence were extracted and written on tape as two individual occurrences. Each extreme value is identified by the coincident values of airspeed, altitude, weight, and so on. Since these data came from the same source as the VGH data, the historical records are applicable to both but are repeated for the convenience of the user. These data are also separated by aircraft type and model. A sample of this data is shown in Figure 1-5.

C-130, MINIMUM AND MAXIMUM GUSTS PER FLIGHT

S	TBA	LBA	MOD	HOURS	MILES	FS	F	GWT	FWT	ALT	A/S	LOD	FS	F	GWT	FWT	ALT	A/S	HIDN
1	123	78	E	0.323	73.1														
1	78	159	E	0.593	145.1	3		100000	17500	9000	275	-0.1	3		100000	17500	9000	275	0.1
1	159	76	F	0.632	153.0	1	1	100000	17500	750	175	-0.1	6		90000	12500	1750	175	0.1
1	76	159	F	0.697	171.5	6	1	120000	25000	750	125	-0.1	1		120000	25000	750	175	0.1
1	159	1	E	0.452	109.5	6	1	100000	25000	1250	175	-0.2	6		100000	25000	5000	225	0.2
1	1	105	F	0.313	65.0	1		130000	25000	3000	175	-0.2	1		130000	25000	3000	175	0.2
1	105	123	F	1.388	347.7	1		100000	17500	3000	175	-0.2	1		100000	17500	1750	175	0.2
1	2	1	F	1.037	250.9	1		130000	25000	750	125	-0.1	6	1	120000	25000	9000	175	0.1
1	1	109	E	0.245	53.2	1		120000	17500	7000	175	-0.1	1		120000	17500	7000	225	0.1
1	105	119	F	0.268	61.4	6	1	120000	17500	1250	125	-0.2	1		120000	17500	750	175	0.1
1	119	105	E	0.253	55.9	6		130000	25000	1750	225	-0.2	6		130000	25000	3000	225	0.3
1	109	127	E	0.335	72.3	1		130000	25000	500	175	-0.2	1		130000	25000	500	125	0.2
1	127	90	E	0.310	65.8	1		120000	17500	3000	225	-0.2	6		120000	17500	5000	275	0.4
1	90	2	E	0.610	143.8	1		100000	17500	5000	175	-0.2	1		100000	17500	3000	175	0.3
2	2	2	E	0.058	8.5														
2	2	78	F	1.915	580.1								6	1	120000	17500	3000	125	0.1
2	124	78	E	0.483	109.2	1		100000	12500	3000	175	-0.2	1	1	100000	12500	1750	175	0.2
2	78	109	E	0.383	84.1	1	1	140000	25000	750	175	-0.1	1	1	140000	25000	1250	125	0.2
2	109	78	F	0.405	89.1	6	1	110000	25000	750	175	-0.1	6		110000	25000	3000	275	0.1
2	78	109	F	0.335	74.3	1		110000	25000	1750	175	-0.1	1		110000	25000	1750	175	0.1
2	103	2	F	1.128	283.9	1		110000	25000	750	175	-0.1	1		110000	25000	750	175	0.3
2	127	125	E	1.[illegible]05	454.5	1		110000	17500	750	175	-0.1	1		110000	17500	750	175	0.2
2	78	132	E	0.758	203.9	6	1	120000	25000	750	125	-0.1	6	1	120000	25000	1250	175	0.1
2	132	103	E	0.618	149.8	1	1	100000	25000	500	175	-0.1	1	1	100000	25000	500	175	0.1
2	1	272	B	0.287	57.2	3		120000	25000	5000	175	-0.1	1		130000	25000	750	175	0.1
2	272	1	B	0.300	60.8	3		100000	17500	5000	225	-0.1	6	1	100000	17500	1250	125	0.1
2	1	272	B	0.295	62.1	1		120000	17500	750	175	-0.2	6		120000	17500	1250	275	0.3
2	272	1	B	0.305	61.0	1		100000	12500	1250	175	-0.1	1		100000	12500	500	125	0.1
2	272	1	B	0.310	61.6	6	1	100000	17500	3000	225	-0.2	6		100000	17500	7000	225	0.2
2	1	272	B	0.463	88.7	1		120000	17500	3000	175	-0.2	1		120000	17500	500	125	0.2
2	250	250	B	1.143	221.5	1		120000	25000	3000	175	-0.3	1		120000	25000	3000	175	0.3
2	1	119	B	0.535	91.6														
2	119	1	B	0.557	120.7	3		100000	17500	7000	225	-0.1							
2	1	119	B	0.342	76.1	6		120000	12500	3000	225	-0.2							
2	119	1	B	0.470	105.5	1		90000	12500	5000	125	-0.1	1		90000	12500	3000	175	0.1
2	1	102	B	0.427	97.5														
2	102	1	B	0.443	104.2	6	1	100000	17500	750	125	-0.1	6		100000	17500	3000	225	0.2
2	1	323	B	0.332	70.6	1		130000	25000	5000	175	-0.1	1		130000	25000	5000	175	0.1
2	323	273	B	0.320	70.8	1		100000	25000	750	175	-0.1	6	1	100000	25000	3000	225	0.2
2	273	323	B	0.338	68.5	1		130000	17500	5000	225	-0.3	1		130000	17500	5000	175	0.4
2	323	1	B	0.253	48.6	1		100000	17500	3000	175	-0.3	6		90000	17500	3000	225	0.3
4	3	5	E	1.575	433.0	1		120000	35000	750	175	-0.1	1		120000	35000	750	175	0.2
4	5	229	F	1.742	456.7	1	1	110000	25000	500	175	-0.1	1	1	110000	25000	500	175	0.1
4	229	3	E	0.365	87.5	1		100000	17500	750	175	-0.1							
4	3	77	E	3.717	1026.8	6		120000	25000	12500	225	-0.4	6		120000	25000	12500	225	0.4
4	77	222	F	2.102	557.9	1	1	120000	35000	750	125	-0.1	1	1	120000	35000	750	125	0.1
4	222	26	E	1.007	265.3								3		100000	17500	17500	225	0.1
4	26	25	E	0.423	91.3	1		120000	35000	1750	175	-0.1	1		120000	35000	1750	175	0.1
4	25	299	F	0.537	121.2								6		120000	25000	9000	225	0.1
4	299	25	F	0.568	122.9	6	1	110000	25000	750	125	-0.1	6	1	110000	25000	750	125	0.1

Season, Takeoff Base, Landing Base, Model, Mission Phase, Flaps Up or Down, Gross Weight, Fuel Weight, Minimum Delta Acc., Maximum Delta Acc.

Figure 1-5. Sample of Extreme Values

TRUE GUST VELOCITY

As mentioned previously, since the true gust velocity data were of short-time duration and collected for continuous analysis purposes only, they cannot be used in statistical work. Each set of true gust velocity data was collected for a specific program, and the description of each program was summarized on magnetic tape. These same data are also presented in the summary data report. This listing is probably not complete, but does reflect recent work. Once it was concluded that there was no way to use these data in conjunction with the VGH data, all positive efforts to obtain this type of data were halted. The example in Figure 1-6, printed directly from the data file, illustrates the information available.

TAPE DESCRIPTION

Two sets of tapes - one in the English and one in the International set of units - have been sent to each of the countries involved in the program. The representative in each country that received the sets is listed in Appendix B along with his address. All correspondence should be directed to the appropriate representative.

A description of the tapes is given in Appendix C.

Copies of these tapes can be made easily and quickly with the user's computer by using programs that are available at his site. All five tapes are physically labelled and the data contained on each tape are further identified on a magnetic label.

COMPUTER PROGRAMS

Along with each set of tapes, a series of programs were delivered. Written in Fortran IV, these programs are on the tapes themselves, and with minor modifications should be easily convertible to the user's computer. One of these programs can generate a copy of a summary data report, described later in this report. Others can generate sets of data that are usually requested.

TRUE GUST VELOCITY

PROGRAM NAME	HICAT
AIRCRAFT	U-2
REPORT NAME	PROJECT HICAT,HIGH ALTITUDE CLEAR AIR TURBULENCE MEASUREMENT AND METEOROLOGICAL CORRELATIONS
REPORT NUMBER	AFFDL-TR-68-127,VOL.I AND II NOVEMBER 1968 AIR FORCE FLIGHT DYNAMICS LABORATORY (FDTE) WRIGHT-PATTERSON AIR FORCE BASE,OHIO 45433 U.S.A.
AUTHORS	W.M.CROOKS,ET AL LOCKHEED-CALIFORNIA COMPANY
GEOGRAPHIC LOCATION	BEDFORD,ENGLAND BARKSDALE AFB,SHREVEPORT,LOUISIANA,USA LORING AFB,LIMESTONE,MAINE,USA ALBROOK AFB,BALBOA,CANAL ZONE,PANAMA PATRICK AFB,COCOA,FLORIDA,USA EDWARDS AFB,EDWARDS,CALIFORNIA,USA
ALTITUDE FLOWN	45000 TO 70000 FEET
INSTRUMENTATION	FIXED VANE GUST PROBE NOSE BOOM
PROCESSING FILTERS	LOW-PASS MARTIN-GRAHAM WITH CUT-OFF AT 1,2,3,5 HZ HIGH-PASS CUT-OFF AT 0.1 HZ PREWHITENING
SAMPLING RATE	12.5 SAMPLES PER SECOND
INTEGRATING TIME	VARIED FROM 1.3 TO 13.3 MINUTES
DATA	PLOTS OF GUST VELOCITY POWER SPECTRA,DATA AFTER 13 MARCH 67

Figure 1-6. True Gust Velocity

SUMMARY DATA REPORT

A copy of a summary data report has been made available to each of the participating countries and other copies can be made by each country from the five tapes. The summary report will contain all data on the tapes except the extreme values which would require an additional 1000 pages. The historical record which will be part of the summary report will identify those aircraft for which extreme values are available.

The format of the files points out that a single record will not fit on a line of paper. Hence, some editing must be done to make the summary report readable. Since only sixteen intervals can be listed (because of paper width), the deleted intervals - the first and last two - will have their data combined with the data in the first and last interval printed.

The summary report is prepared primarily for persons who will use the tapes so that they may see what and how much data are available. The data will be presented in the finest breakdown possible and will contain all of the original data. In this form the data can be used for manual calculations, but much effort would be required to combine the fine breakdowns into coarser but more useable groupings. The number of people who can use these very fine breakdowns is generally limited to people who process data. This and the size of the summary report are the only reasons that the distribution is limited. The summary report contains, therefore, in addition to a listing of all programs, and a description of the contents of all tape reels, the following:

1. Listing of all of the original cumulative acceleration distributions with the associated time and distance versus weight, altitude, and airspeed ranges by aircraft type and model for each season and further separated by flaps in or out and flight segments if this information is available. Each listing by aircraft is preceded by the historical record.

2. Bivariate distribution of the cumulative gust frequency per mile by altitude and season for each set of data by aircraft type. Normally there is one set of data for each aircraft type. However, the addition of parameters or finer parameter intervals during the course of the data collection resulted in three distinct sets of data for the C-130 and two for the B-52. These sets of data correspond to the plots shown in Section 3 of this report and are derived from the VGH data files.

3. Direct copy of part of each tape. This is commonly referred to as a dump by programmers and is useful only to them.

4. Description of each program submitted concerning what it will do and how it can be used.

SUMMARY OF ALL DATA

A summary of the data available from either the tape or the summary report is given in Table 1-1. The characteristics of the aircraft on which the data was recorded are given in Table 1-2.

The summary represents only that data that could be used and does not reflect over 25,000 hours of data made available by the Netherlands, and a similar amount made available by France. Both sets of data were recorded on counting accelerometers and included both ground and flight data. Even if some means were found to isolate the flight data, and to further separate the turbulence data from the maneuver data, the absence of the corresponding airspeed, altitude, and weight would still make the data unuseable. Some three thousand hours of German data will not be ready until next year. Italy had some extreme values that were very interesting and potentially useful, but were reluctantly omitted from the summary since only exceedances over a certain limit were reported, in great detail, and no knowledge was available on the size or number of the extreme values below these limits on the other flights.

TABLE 1-1

Summary of Available Data

Model	Data Hours	Distance N.M.	Altitude Range(ft)	Geographic Location	Extreme Value(hrs)	Additional Constraints	Source
C-130A,B,E	9,340	2,312,000	0-35,000	CONUS	8,403	S	U.S.A.
C-130B,E	7,650	1,851,000	0-35,000	SEA	7,651	FW,F,S,FC	U.S.A.
C-130A,B,E	11,210	2,626,000	0-35,000	CONUS,TRATL TRPAC	12,047	FW,F,S,FC	U.S.A.
C-141	39,200	14,580,000	0-40,000	CONUS,TRATL TRPAC	37,831	S,FC	U.S.A.
B-52B,F	12,503	4,851,900	0-50,000	CONUS	--	FC	U.S.A.
B-52C,H	14,297	5,167,000	0-50,000	CONUS,TRPAC	--	F,FC,S	U.S.A.
B-58	5,770	2,881,000	0-50,000	CONUS	--	FC	U.S.A.
B-26	2,076	424,000	0-20,000	CONUS	2,076	S	U.S.A.
F-4	2,950	1,186,000	0-50,000	CONUS	2,142	S	U.S.A.
T-38	2,876	1,080,000	0-40,000	CONUS	1,706	S	U.S.A.
OV-1	204	36,200	0-15,000	CONUS	204	S	U.S.A.
707-220	1,154	495,800	0-35,000	CONUS	--	--	U.S.A.
707-320	2,830	1,266,870	0-40,000	CONUS	--	--	U.S.A.
707-420	4,152	1,838,300	0-40,000	CONUS,TRATL	--	--	U.S.A.
DC-8-30	500	218,350	0-40,000	CONUS	--	--	U.S.A.
CV-880	3,766	1,661,390	0-40,000	CONUS	--	--	U.S.A.
Caravelle	723	242,580	0-35,000	CONUS	--	--	U.S.A.
727-200	994	401,560	0-35,000	CONUS	--	--	U.S.A.
DC-7C	1,728	428,960	0-20,000	CONUS	--	--	U.S.A.
BAC-111	1,156	389,140	0-35,000	CONUS	--	--	U.S.A.
CL-44 Cargo	1,179	373,580	0-30,000	CONUS	--	--	U.S.A.
300-LR	186	56,300	0-35,000	Canada,TRPAC	--	--	Canada
DC-4M	85	16,130	0-20,000	Canada	--	--	Canada
C-119	65	11,000	0-10,000	Canada,Greenland	--	--	Canada
680-E	25	4,170	0-10,000	Canada	--	--	Canada
D-18-S	137	18,200	0-10,000	Canada	--	--	Canada
SA-16B	62	8,290	0-10,000	Canada	--	--	Canada
CL-44	3,056	929,660	0-35,000	N.A.,TRATL,TRPAC	--	--	Canada
Transall	84	21,500	0-5,000	France	84	--	France &Germany
Ambassador	893	178,000	0-21,000	EUR	--	S,FC	U.K.
Britannia	1,228	363,000	0-27,000	I.O.,AFR,EUR,M.F.E.	--	S,FC	U.K.
Comet 1	1,809	610,000	0-44,000	EUR,AFR	--	S,FC	U.K.
Comet 4	1,185	477,500	0-41,000	EUR,AFR,M.F.E.,AUS	--	S,FC	U.K.
Bristol	1,346	189,400	0-11,000	EUR,AFR,AUS	--	S,FC	U.K.
Hermes 4,4A	4,601	1,029,900	0-22,000	EUR,AFR,M.F.E.	--	S,FC	U.K.
Stratocruiser	3,378	765,000	0-25,000	TRATL,N.A.	--	S,FC	U.K.
Superconstellation	3,766	904,500	0-22,000	EUR,AFR, M.F.E.,TRPAC	--	S,FC	U.K.
Viking	1,324	230,000	0-14,000	EUR,AFR	--	S,FC	U.K.
Viscount	3,390	946,900	0-28,500	EUR,AFR	--	S,FC	U.K.
707	2,240	975,100	0-40,000	EUR,AFR,M.F.E., AUS,TRATL	--	S,FC	U.K.

Geography Code

CONUS	Continental United States
SEA	Southeast Asia
TRATL	Trans-Atlantic
TRPAC	Trans-Pacific
N.A.	North America
EUR	Europe
M.F.E.	Mid- and Far-East
AFR	Africa
AUS	Australia
I.O.	Indian Ocean

Constraint Code

F	Flaps
S	Season
FC	Flight Condition
FW	Fuel Weight
W	Weight
H	Altitude
A	Airspeed

NOTE: W,H,A apply to all aircraft.

TABLE 1-2

Aircraft Characteristics

Model	Maximum Gross Weight (lb)	Wing Area (ft²)	Mean Chord (ft)	Span (ft)	A & N_0 Basis
C-130	135,000-155,000	1745	13.7	132.6	8 DOF
C-141	318,000	3228	22.17	159.9	6 DOF
B-52	460,000-500,000	4000	22.96	185.0	16-30 DOF
B-58	175,000	1542	36.17	56.8	6 DOF
B-26	41,000	540	7.72	71.5	1 DOF
F-4	56,000	530	16.05	38.4	1 DOF
T-38	11,700	170	7.73	25.2	1 DOF
OV-1	15,000	330	8.16	42.0	1 DOF
707-220	248,000	2433	20.1	130.8	1 DOF
707-320	312,000	2892	22.69	142.4	1 DOF
707-420	312,000	2892	22.69	142.4	1 DOF
DC-8-30	310,000	2773	22.1	142.4	1 DOF
CV-880	185,000	2000	18.98	120.0	1 DOF
Caravelle	110,230	1579	14.03	112.5	1 DOF
727-200	152,000	1650	14.4	108.0	1 DOF
DC-7C	143,000	1637	13.7	127.5	1 DOF
BAC-111	76,500	980	11.08	88.5	1 DOF
CL-44 Cargo	210,000	2075	16.07	142.3	1 DOF
300LR	140,000	2075	14.67	--	1 DOF
DC-4M	73,000	1457	13.64	117.5	1 DOF
C-119	64,000	1447	14.02	109.3	1 DOF
680-E	8,000	255	5.84	49.5	1 DOF
D-18-S	8,000	374	13.61	46.0	1 DOF
SA-16-B	40,000	1035	11.46	96.7	1 DOF
CL-44	205,000	2075	16.07	142.3	1 DOF
Transall	98,600	1723	13.7	131.2	
Ambassador	61,800	1200	10.42	114.8	1 DOF
Britannia	176,400	1205	10.52	114.2	1 DOF
Comet 1	110,200	2015	17.50	114.8	1 DOF
Comet 4	162,000	2120	18.45	114.8	1 DOF
Bristol	45,200	1487	13.78	107.9	1 DOF
Hermes 4, 4A	99,200	1408	12.46	112.8	1 DOF
Stratocruiser	160,000	1769	12.50	141.1	1 DOF
Superconstellation	137,500	1650	14.67	123.0	1 DOF
Viking	35,200	882	9.89	89.2	1 DOF
Viscount	64,500	963	10.22	94.2	1 DOF
707	316,000	2890	22.69	142.4	1 DOF

SECTION 2

During the past few years, advances have been made in the analysis of airplane behavior in rough air through the application of the theory of random processes and the techniques of generalized harmonic analysis (References 3 to 9). The application of these techniques is based upon the representation of atmospheric turbulence as a continuous random disturbance characterized by power-spectral-density (PSD) functions and certain probability distributions (Reference 2). The power spectrum of atmospheric turbulence shows the contribution of different frequencies of turbulent air flow to the mean square velocity of the turbulence. The total area under the curve is the mean square velocity (Reference 32). The power spectrum of the turbulence is then used along with the airplane response characteristics to determine the power spectra and other statistical characteristics of the airplane loads or motions in rough air. The application of this approach to the problem of calculating load and other histories for operational flight requires detailed information on the spectrum of turbulence in the atmosphere (Reference 2).

The Lo-Locat program is establishing a definition of atmospheric turbulence near the ground for use in aircraft design criteria. Twenty-mile segments of low-altitude turbulence have been found to be isotropic and homogeneous with statistically independent gust velocity components. Lo-Locat has shown that gust velocity spectra are closely represented by the Von Karman expressions (Reference 10). Members of the advising committee, on the basis of their own or related work, also recommended this expression.

The Von Karman expression (Reference 31), or the isotropic turbulence equation, is

$$\phi(\Omega) = \sigma_w^2 \cdot \frac{L}{\pi} \cdot \frac{1 + 8/3(1.339L\Omega)^2}{[1 + (1.339L\Omega)^2]^{11/6}} \qquad (1)$$

where

$\Omega = 2\pi/\lambda = \omega/V$ and

λ = wave length ~ feet

ω = frequency ~ radians/second

V = aircraft velocity ~ feet/second

L = scale length ~ feet

σ_w = root-mean-square (RMS) of the gust velocity

w = wind speed ~ feet/second

A graph of the model is shown in Figure 2-1.

For large Ω, $\phi(\Omega)$ decays with a slope of -5/3 which decay is supported by some data and by Kolmogoroff's similarity theory (Reference 33).

L, the scale of turbulence, is dependent on altitude, and has been defined variously by different investigators. Two of these are as follows: L can be considered proportional to the eddy size (Reference 2), and L defines the frequency at which the bend in the spectrum occurs (approximately $\Omega L = 1$). This latter definition can be found in many reports. For the processing of these data, the assumption that L equals altitude up to 2500 feet and is constant 2500 feet thereafter was made.

While the Von Karman spectrum has been assumed for this program, various other spectra have been developed by other investigators. Among these are J. L. Lumley and H. A. Panofsky (Reference 24), and H. L. Dryden (Reference 25). A more general description is given in Reference 12.

The spectral density varies with σ_w and L, that is, with the standard deviation or the root-mean-square of the gust velocity and the scale of turbulence. The square of σ_w in turn varies appreciably with weather conditions. The probability distribution of σ_w is not required for this program. A detailed development of this density function can be found in Reference 2.

The probabilities of encountering the various conditions of atmospheric turbulence can be derived from the data collected from the contributing NATO countries. These data have been obtained from airplane acceleration measurements in normal operations, and given in the form of the number of peak counts - or, in a few instances, level crossings - that exceed given values.

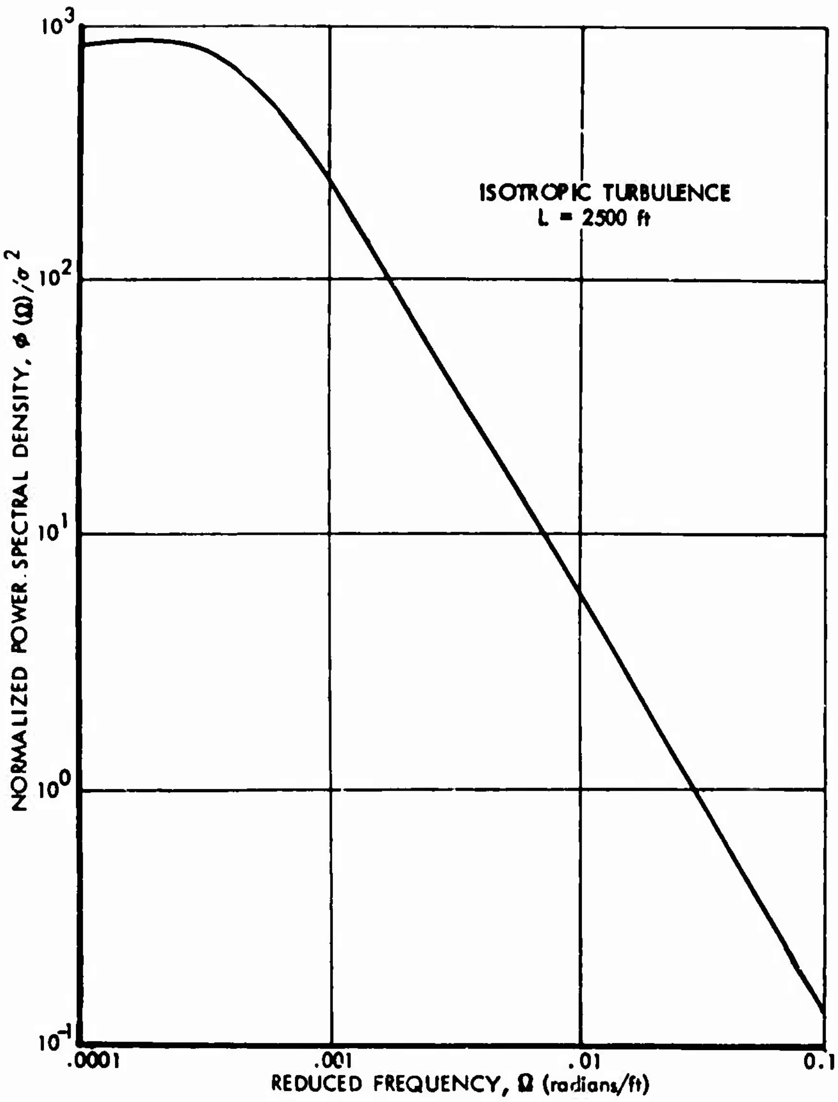


Figure 2-1. Gust Power Spectral Density Function

Fortunately, in the theory of random processes, relations have been derived (Reference 14) between level crossings which are related to peak counts (such as have been made for normal acceleration) and the associated power spectra. These relations apply to the case of a stationary Gaussian random process. A very brief summary of the statistical concepts involved is given, but more details can be found in any book on stochastic processes.

The power spectral density is the Fourier transform of the autocorrelation function, that is,

$$\phi(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} R(\tau)e^{-i\omega\tau}\, d\tau$$

where ω is angular frequency in radians per second.

DERIVATION OF CONVERSION TECHNIQUES

In many recent studies of airplane behavior in rough air, atmospheric turbulence is generally considered a stationary Gaussian random process. The assumption that turbulence is a Gaussian random process appears warranted by the approximately Gaussian character of turbulent velocity fluctuations. However, for present purposes (in which the overall gust and load experiences of an airplane in operational flight are of concern), the process cannot be considered a simple stationary one, inasmuch as the turbulence characteristics of the atmosphere vary widely with weather conditions, particularly in regard to the intensity of the turbulence.

In order to account for the variations in atmospheric turbulence with weather conditions, it will be assumed that turbulence is only locally Gaussian and stationary; that is, its statistical characteristics are Gaussian and invariant in a given restricted region and for a short time, but vary, particularly in intensity, from time to time and place to place. This assumption implies that the region or time is small relative to the entire flight path or flight duration but large enough for statistical equilibrium. On this basis, the overall turbulence experienced by an airplane in given operations is taken to consist of the summation for appropriate exposure times to a series of elemental stationary Gaussian processes (Reference 2).

If the airplane response to turbulence is linear, as assumed in the present analysis, the response, such as the load history, to each elemental turbulence process, is likewise a Gaussian process, and the overall operational load history may in turn also be considered to consist of a summation of the loads for various elemental Gaussian turbulence disturbances. This scheme serves to yield a reasonable approximation of the actual airplane load history and, further, has the particular advantage for present purposes of permitting the use of relations between peak counts and spectra derived for the stationary Gaussian case in Reference 14. (Reference 2)

RELATIONS BETWEEN NUMBER OF PEAKS AND SPECTRA

The asymptotic relation between the average number of maximums per second exceeding a given value and the spectrum of a stationary Gaussian disturbance y(t) has been derived in Reference 14 and is for large values of y given by

$$N(y) = \frac{1}{2\pi}\left\{\frac{\int_0^\infty \omega^2\phi(\omega)d\omega}{\int_0^\infty \phi(\omega)d\omega}\right\}^{1/2} e^{-y^2/2\sigma^2} \qquad (2)$$

where

$N(y)$ = average number of maximums per second exceeding given values of y

ω = frequency ~ radians/second

$\phi(\omega)$ = power-spectral-density function of a random disturbance y(t)

$$\sigma^2 = \int_0^\infty \phi(\omega)d\omega \qquad (2.1)$$

Equation (2) is the exact expression for the number of crossings per second with positive slope of given values of y, but is an approximate expression for the number of maximums above a given value of y.

Members of the advisory committee investigated the relationship between the number of peak-between-mean countings and the number of level crossings since practically all of the available data represent peak-between-mean readings. No useable relationship could be defined within the allowable time frame. Hence equation (2) is assumed to be an adequate approximation for the number of level crossings. The cumulative frequencies in the lower intervals of the gust velocity are therefore affected since they are underestimated. No general statement of this underestimation can be made since it is dependent upon the RMS (σ) value, the bandwidth, and the shape of the transfer function.

Given a function of time (or distance whose ordinate varies randomly in time), such as the example shown in Figure 2-2

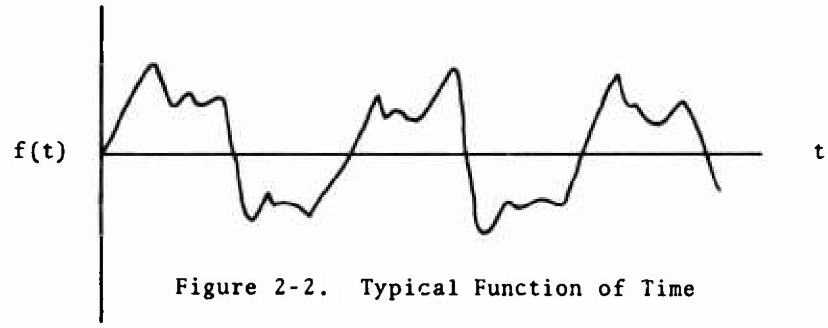


Figure 2-2. Typical Function of Time

Actually there exists an entire class of such functions $f_i(t)$; a value of i yields a representative of the family. A different value yields, of course, a completely different time history, the relation between the two being defined in a statistical sense.

Stationarity: The statistical properties of $f_i(t)$ do not vary with time, t; that is, the statistical properties of the time history, such as its mean, its root-mean-square, its power spectral density, and so on, do not change with time.

Ergodicity: Averages over i are equivalent with averages over t.

Normality: Gaussian means the same. The distribution over i of $f_i(t)$ ordinates are governed by a normal distribution (single value of t and all joint distributions of $t_1, t_2, \ldots, t_k$). With ergodicity, this distribution can be obtained from a single trace.

Autocorrelation: For stationary processes, the correlation between f(t) values is a function only of the time lag, τ. If the process is ergodic, the autocorrelation R(τ) is

$$R(\tau) = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} f(t)f(t+\tau)dt$$

$$\sigma^2 = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} f^2(t)dt = R(0)$$

$$\text{mean of } f(t) = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} f(t)dt = \overline{f(t)}$$

Examination of equation (2) indicates that the number of peaks per second above given values depends upon σ^2 (the denominator), which is the area under the spectrum, and upon the second moment of the spectrum about the origin (the numerator).

From Reference 14, a second form of equation (2) is

$$N(y) = N_0 e^{-y^2/2\sigma^2} \tag{3}$$

which can also be obtained from equation (2) by letting y = 0. N_0 has the dimensions of a frequency and can be considered a characteristic frequency of the random disturbance y(t).

CONVERSION OF ACCELERATION DATA TO ROOT-MEAN-SQUARE GUST VELOCITY

If the input (atmospheric turbulence) has the desired statistical properties and if the aircraft is a linear system, then the response of the aircraft (acceleration) has the same statistical properties. If it is assumed that the spectral shape of turbulence is invariant with weather conditions (as suggested by available measurements), and varies only in intensity or root-mean-square-velocity, the output spectrum, $\phi_n(\omega)$, for an acceleration, n(t), for a given airplane, under given operating conditions (fixed speed, weight, altitude, etc.), is likewise invariant in shape. Then

$$n = \text{some constant} \cdot w = \bar{A} \cdot w \tag{4}$$

$$\sigma_n^2 = \bar{A}^2 \cdot \sigma_w^2 \tag{5}$$

where n is the vertical acceleration of the aircraft

w is the gust velocity.

Equation (3) may now be written as

$$N(w) = N_{0,w} e^{-w^2/2\sigma_w^2} \tag{6}$$

and for the response to w of n

$$N(n) = N_{0,n} e^{-n^2/2\sigma_n^2} \tag{6.1}$$

where $N_{0,w}$ is the characteristic frequency of the gust velocity

$N_{0,n}$ is the characteristic frequency of the aircraft response.

$$\frac{N(w)}{N(n)} = \frac{N_{0,w}}{N_{0,n}} \cdot \frac{e^{-w^2/2\sigma_w^2}}{e^{-n^2/2\sigma_n^2}}$$

Using equations (4) and (5), the exponential factors cancel resulting in

$$N(w) = \frac{N_{0,w}}{N_{0,n}} \cdot N(n) \tag{7}$$

Thus the number of positive slope crossings of any level of gust velocity, w, can be obtained from the number of positive slope crossings of the corresponding response, n, by multiplying the latter by the ratio of the characteristic frequency of the gust velocity to the characteristic frequency of the response of the aircraft. This method is valid even if the process is only locally stationary and Gaussian.

The root-mean-square gust acceleration in rough air is related to the turbulence spectrum and the airplane response characteristics by the following equation:

$$\sigma_n^2 = \int_0^\infty \phi_w(\omega)T^2(\omega)d\omega \tag{8}$$

$$= \int_0^\infty \phi_n(\omega)d\omega \tag{8.1}$$

where $\phi_w(\omega)$ is the power spectrum of vertical gust velocity

$\phi_n(\omega)$ is the power spectrum of airplane normal acceleration

$T(\omega)$ is the amplitude of airplane acceleration response to sinusoidal gusts of unit amplitude (transfer function). (Reference 2)

Equation (8.1) is the same as (2.1). Changing subscripts from n, acceleration, to w, gust velocity, yields

$$\sigma_w^2 = \int_0^\infty \phi_w(\omega)d\omega \tag{8.2}$$

Equation (8) is useful when the transfer function is known. When the transfer function is not known, the following simplification can be used.

As a preliminary effort in this direction, it will be assumed that:

(1) The airplane is rigid.

(2) The airplane is free to move vertically only (not pitch).

(3) A spectrum of turbulence is assumed.

For the foregoing condition, a useful result obtained by Y. C. Fung (Reference 4) is that

$$\overline{\ddot{Z}^2} = \sigma_w^2 \frac{16V^2}{\bar{c}^2(1 + K)^2} \cdot \frac{I(K,s)}{\pi} \tag{9}$$

where $\overline{\ddot{Z}^2}$ = mean square acceleration

$\bar{c}$ = mean aerodynamic chord

K = airplane mass parameter, $\dfrac{W}{g\pi\rho S\bar{c}}$

s = ratio of the mean chord to the scale of turbulence, $\bar{c}/L$.

Since $K \gg 1$ in almost all cases of concern, and when m is substituted for 2π, equation (9) can be simplified to yield

$$\sigma_n = \frac{\sigma_w \rho V S m}{2W} \sqrt{\frac{I(K,s)}{\pi}} \tag{10}$$

$$\text{and } \sigma_n = \bar{A}\,\sigma_w \tag{11}$$

where

$$\bar{A} = \frac{\rho V S m}{2W} \sqrt{\frac{I(K,s)}{\pi}} \tag{12}$$

and $\sqrt{\frac{I(K,s)}{\pi}}$ is an airplane gust-response factor. (Reference 2)

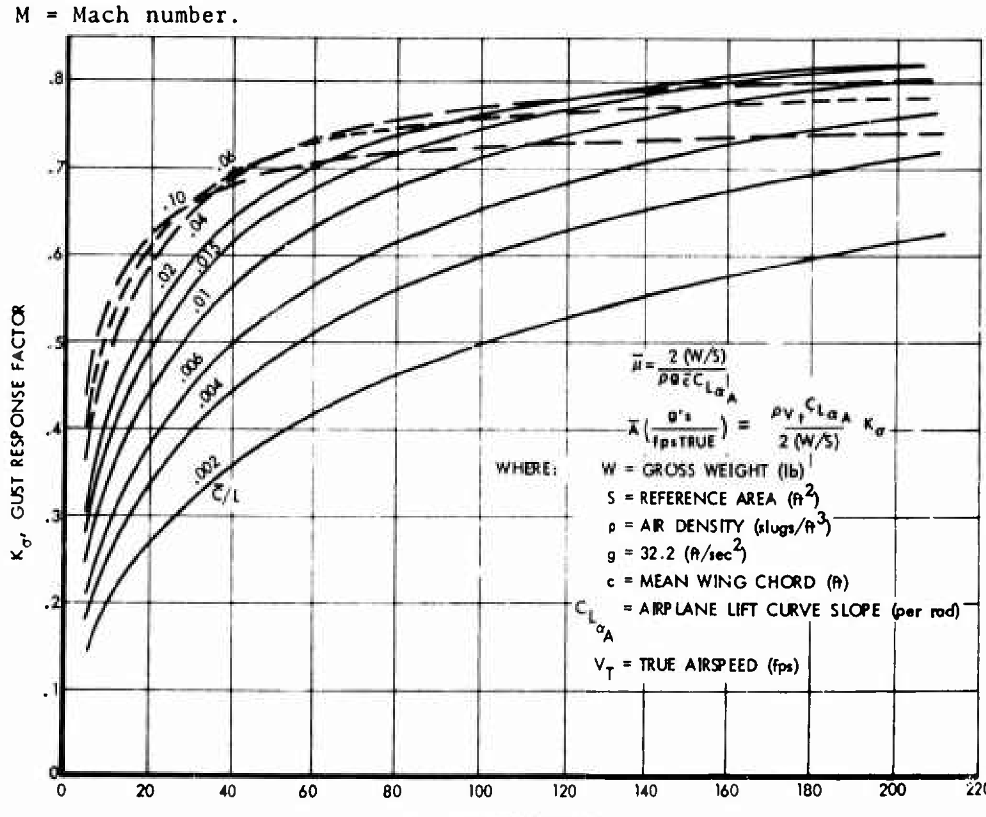
The derivation by Fung (Reference 4) of equation (9) was based on 2-dimensional strip theory, a Liepman approximation of the frequency response of the lift, a simplification of the frequency response of the airplane, and the Liepman gust spectrum. The influence of the gust spectrum is restricted to the evaluation of the gust response factor $\sqrt{\frac{I(K,s)}{\pi}}$, commonly referred to as K_σ. Thus, since the Von Karman spectrum is desired in the present work, a revised evaluation of K_σ is needed from that used by Fung or Reference 2. Fortunately, such a presentation is made by Hoblit, et al., in Reference 13. These curves were used in the present program for K_σ and are presented in Figure 2-3. A note should be made that the lift curve slope, m, in equations (10) and (12) is the three-dimensional slope for the wing only. Hoblit modified the wing lift slope by a factor of 1.15 in his derivation to account for the total airplane lift curve slope. The present work used actual airplane values where obtainable, or the one-dimensional NASA approximation for the wing airplane lift curve slope given by:

$$C_{L_\alpha} = \frac{6A\cos\Lambda}{A + 2\cos^2\Lambda} \cdot \frac{A + 2\cos\Lambda}{A\sqrt{1 - M^2\cos^2\Lambda} + \cos\Lambda}$$

where A = wing aspect ratio

Λ = wing sweep angle at 1/4 chord

M = Mach number.



(a) $\bar{\mu}$ = 0 TO 200

Figure 2-3. Gust Response Factor for Isotropic Turbulence Spectrum

Equation (11) is not restricted to the one-degree-of-freedom case and can be generalized by substituting equations (8) and (8.2) in equation (11) as follows:

$$\bar{A} = \sigma_n/\sigma_w$$

$$= \left\{ \frac{\int_0^\infty \phi(\omega)T^2(\omega)d\omega}{\int_0^\infty \phi(\omega)d\omega} \right\}^{1/2} \tag{13}$$

If Ω is used instead of ω, where $\Omega = \omega/V$, a more convenient form of the equation is obtained and one which agrees with the notation used to define the Von Karman spectrum at the beginning of this section. This new form gives

$$A = \left\{ \frac{\int_0^\infty \phi(\Omega)T^2(\Omega)d\Omega}{\int_0^\infty \phi(\Omega)d\Omega} \right\}^{1/2} \tag{14}$$

In a similar manner equation (2) can be expressed in terms of Ω for both the input spectrum and the response spectrum. The notation used is the same notation used in equations (6) and (7). Equation (2), evaluated at $y = 0$, for the input spectrum

$$N_w(0) = N_{0,w} = \frac{1}{2\pi} \left\{ \frac{\int_0^\infty \omega^2\phi(\omega)d\omega}{\int_0^\infty \phi(\omega)d\omega} \right\}^{1/2}$$

$$= \frac{V}{2\pi} \left\{ \frac{\int_0^\infty \Omega^2\phi(\Omega)d\Omega}{\int_0^\infty \phi(\Omega)d\Omega} \right\}^{1/2} \tag{15}$$

The response spectrum $\phi_n(\omega)$ can be expressed in terms of the input spectrum from equation (8) is

$$\phi_n(\omega) = T^2(\omega)\phi(\omega)$$

Then substituting $\Omega = \omega/V$ would yield

$$N_n(0) = N_{0,n} = \frac{V}{2\pi} \left\{ \frac{\int_0^\infty \Omega^2\phi(\Omega)T^2(\Omega)d\Omega}{\int_0^\infty \phi(\Omega)T^2(\Omega)d\Omega} \right\}^{1/2} \tag{16}$$

where $\phi(\Omega)$ is the Von Karman spectrum

and V = airspeed ~ feet/second

$\Omega = 2\pi\lambda = \omega/V$

ω = frequency ~ radians/second.

For the graphs presented in Section 3, true airspeed is used.

The methods used to process the acceleration data were based on the one-degree-of-freedom $\bar{A}$ defined in equation (12) or the $\bar{A}$ generated from equation (13) if the transfer function was known.

The integration was done over a range of 0 to b for both spectra where b was defined by the bandwidth used in deriving the transfer function. This same limit was used to derive the characteristic frequencies defined in equations (15) and (16). For the characteristic frequency the integral is divergent as b increases without bound. Hence the characteristic frequency of the response function is highly sensitive to this chosen upper limit, which must be defined by the response characteristics of the aircraft.

The characteristic frequency of the response function is 1 for the one-degree-of-freedom case.

The difference between the one-degree-of-freedom $\bar{A}$ and the multi-degree-of-freedom $\bar{A}$ is illustrated in Figure 2-4 where $\bar{A}$ values for various conditions of airspeed, altitude, and weight are generated for both eight and one degrees of freedom for one aircraft.

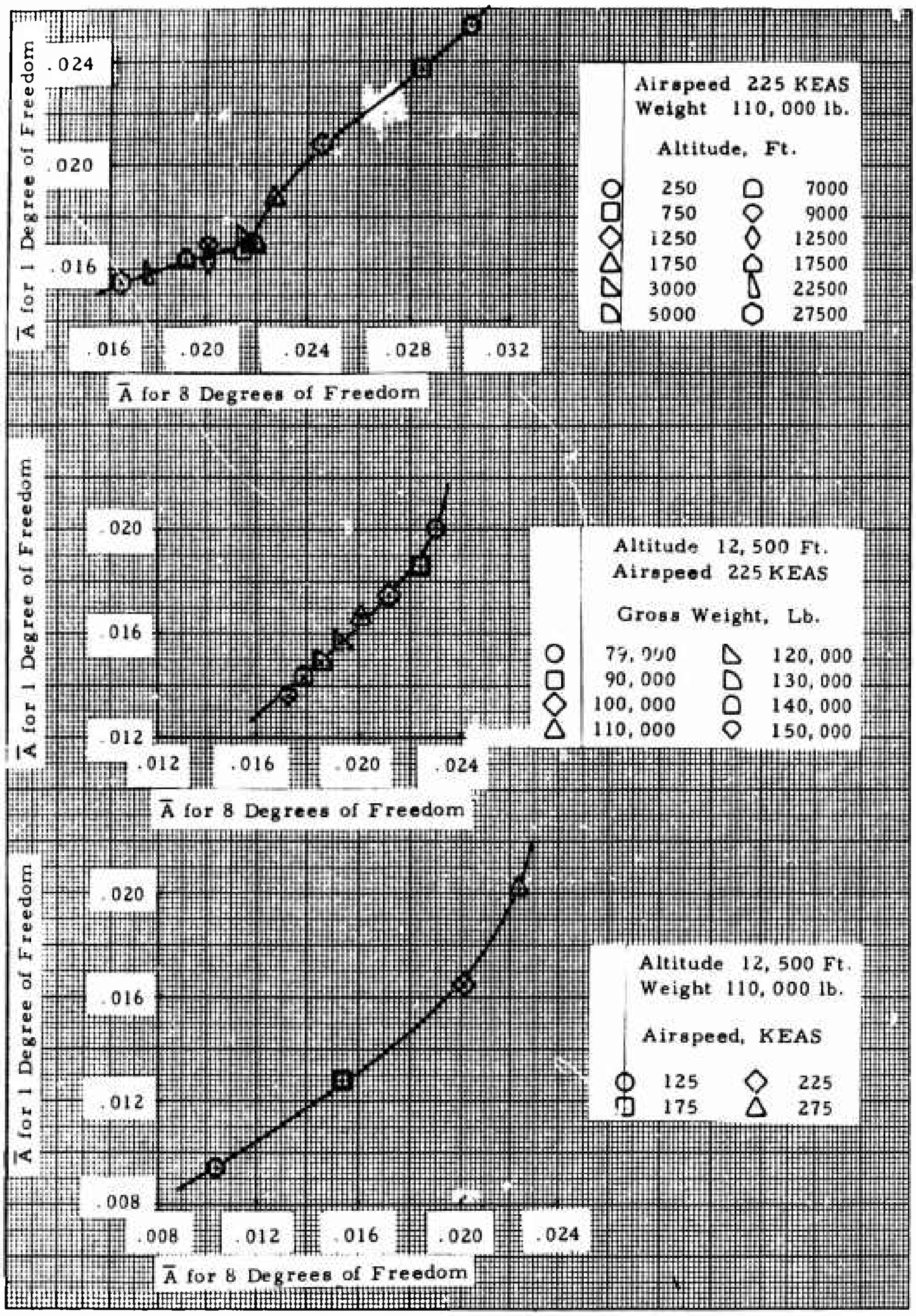


Figure 2-4. Comparison of $\bar{A}$ Values Derived from 1 DOF and 8 DOF for C-130 Aircraft

SUMMARY OF THE PROCESSING OF THE ACCELERATION DATA

The original data are available as a cumulative distribution of the number of occurrences of Δn, the vertical acceleration minus 1g, for sets of constant weight, altitude, and airspeed. Each of the last three parameters defines an interval, with the constant value being the lower limit of the interval. The Δn values also represent intervals.

Each Δn is divided by $\bar{A}$ where $\bar{A}$ is derived for the averages of each set of weight, altitude, and airspeed for each aircraft from

$$\bar{A} = \frac{\rho VSm}{2W} \cdot K_\sigma$$

or

$$\bar{A} = \left\{ \frac{\int_0^b \phi(\Omega) T^2(\Omega) d\Omega}{\int_0^b \phi(\Omega) d\Omega} \right\}^{1/2}$$

and $N_{0,n}$ from

$$N_{0,n} = 1$$

$$N_{0,n} = \frac{V}{2\pi} \left\{ \frac{\int_0^b \Omega^2 \phi(\Omega) T^2(\Omega) d\Omega}{\int_0^b T^2(\Omega) \phi(\Omega) d\Omega} \right\}^{1/2}$$

and $N_{0,w}$ from

$N_{0,w} = 1$ for one degree of freedom

$$N_{0,w} = \frac{V}{2\pi} \left\{ \frac{\int_0^b \Omega^2 \phi(\Omega) d(\Omega)}{\int_0^b \phi(\Omega) d\Omega} \right\}^{1/2}$$

where

$$\phi(\Omega) = \sigma^2_w \frac{L}{\pi} \frac{1 + 8/3(1.339L\Omega)^2}{[1 + (1.339L\Omega)^2]^{11/6}}$$

and

$\bar{A}$ = aircraft response

ρ = density

V = true airspeed ~ feet/second

S = wing area ~ feet²

m = slope of the lift curve per radian

W = weight of aircraft ~ pounds

K_σ = gust alleviation factor based on the Von Karman spectrum

b = cut-off frequency

Ω = $2\pi/\lambda = \omega/V$

$T(\Omega)$ = transfer function, amplitude of aircraft acceleration response to unit amplitude sinusoidal gusts

$N_{0,n}$ = characteristic frequency of the aircraft response per second. N_0 is used on the plots in Section 3.

$N_{0,w}$ = characteristic frequency of the Von Karman spectrum per second. N_0' is used on the plots in Section 3.

$\phi(\Omega)$ = Von Karman spectrum

ω = frequency ~ radians/second

λ = wave length

L = scale of turbulence L = h for h≤2500'

L = 2500 for h>2500

h = altitude ~ feet.

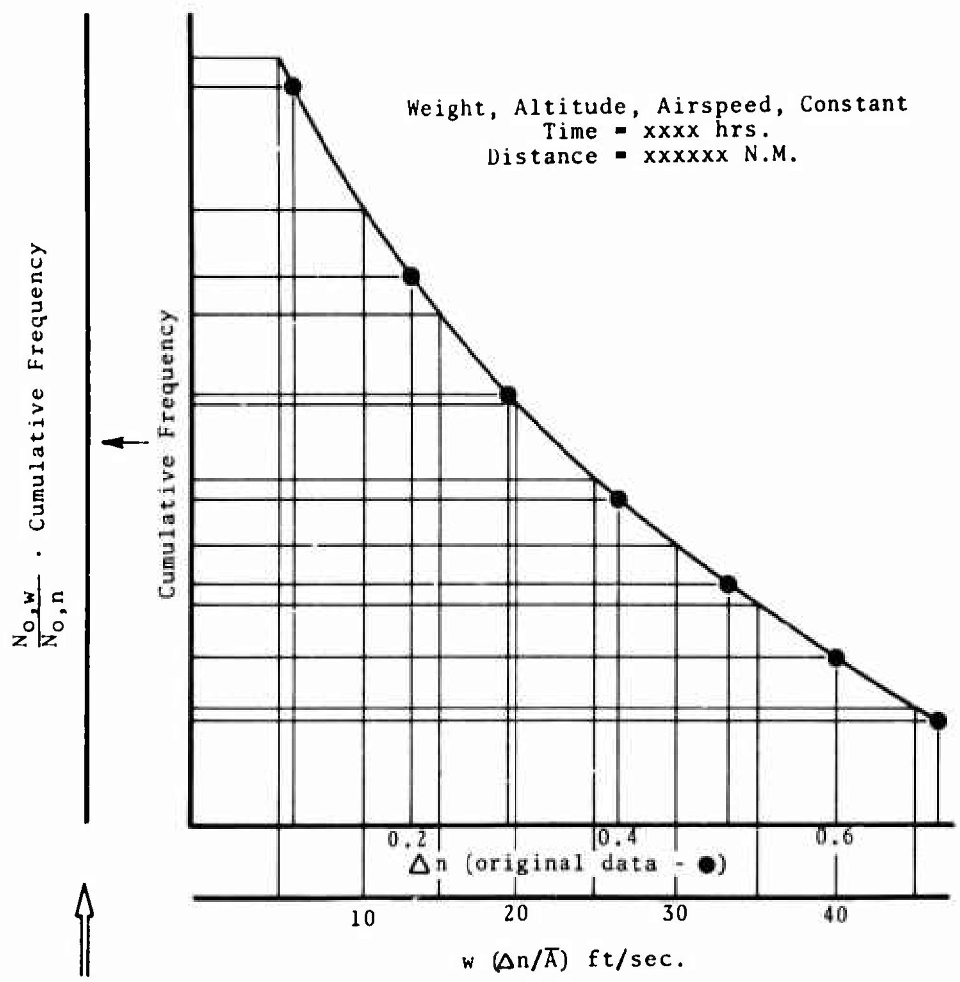
Since $\Delta n/\bar{A}$ is normally a decimal, new frequencies were derived corresponding to $\Delta n/\bar{A}$ at 5 feet/second intervals (or 2 meters/second).

These new frequencies were multiplied by $N_{0,w}/N_{0,n}$ (or $\frac{N_0'}{N_0}$).

These resultant frequencies are divided by the number of nautical miles the aircraft traveled for this set of data. This division is made just prior to printing the data, since the data on tape does not reflect it.

The graphic details of the transposition from acceleration frequencies to gust frequencies is shown in Figure 2-5.

Additional references that either expand on the derivations covered in Section 2 or discuss the applications of power spectral density techniques can be found in References 26 through 33.



These modified frequencies divided by total miles after the data is combined.

Figure 2-5. Graphical Representation of the Processing

SECTION 3

PRESENTATION OF THE DATA

Extreme Values

Although no extreme values are listed in the summary report, one plot, taken from Dr. Buxbaum's paper (Reference 18) and derived by using only extreme values from C-130 data, is presented as Figure 3-1 in this section. This is inserted to show what information can be gained by using relatively little data. Extreme values of gust velocities encountered once per flight or flight segment by aircraft flying under different conditions, can be used to calculate the possible scatter of the cumulative frequency distributions. These same values are useful in predicting the occurrence of rare events such as upsets. The brevity in the treatment of this method results only from lack of time and funds and in no way results from lack of interest. References 16 and 17 treat the methods in detail and their reading is highly recommended. Since the extreme values are written on one tape, a listing of the set desired can be made easily from that tape.

Plots

Plots of vertical gust velocity are presented in graphical form at the end of this report. In general they represent frequency of occurrence per nautical mile versus gust velocity plotted for each altitude by season. For each set of data the total hours are given for that set, along with the number of nautical miles of data recorded for each subset of data. For example, for the C-130 data recorded in Southeast Asia operations, 195 hours of data were recorded in the altitude band of sea level to 500 feet. The number of miles recorded is separated by season as follows:

Winter	8195	nautical miles
Spring	4882	" "
Summer	5234	" "
Autumn	9040	" "

Where both positive and negative gust velocities are plotted, the original data identified the accelerations as positive and negative. Where only positive gust velocities are presented, the original data combined the positive and negative accelerations. However, during processing of the data into gust velocities, the frequencies were halved.

Where the frequencies are multiplied by N_0'/N_0, transfer functions or A and N_0 values were available from the aircraft manufacturer and were used.

Where the frequencies are unweighted, a one-degree-of-freedom $\bar{A}$ was used, and the recorded frequencies are unchanged.

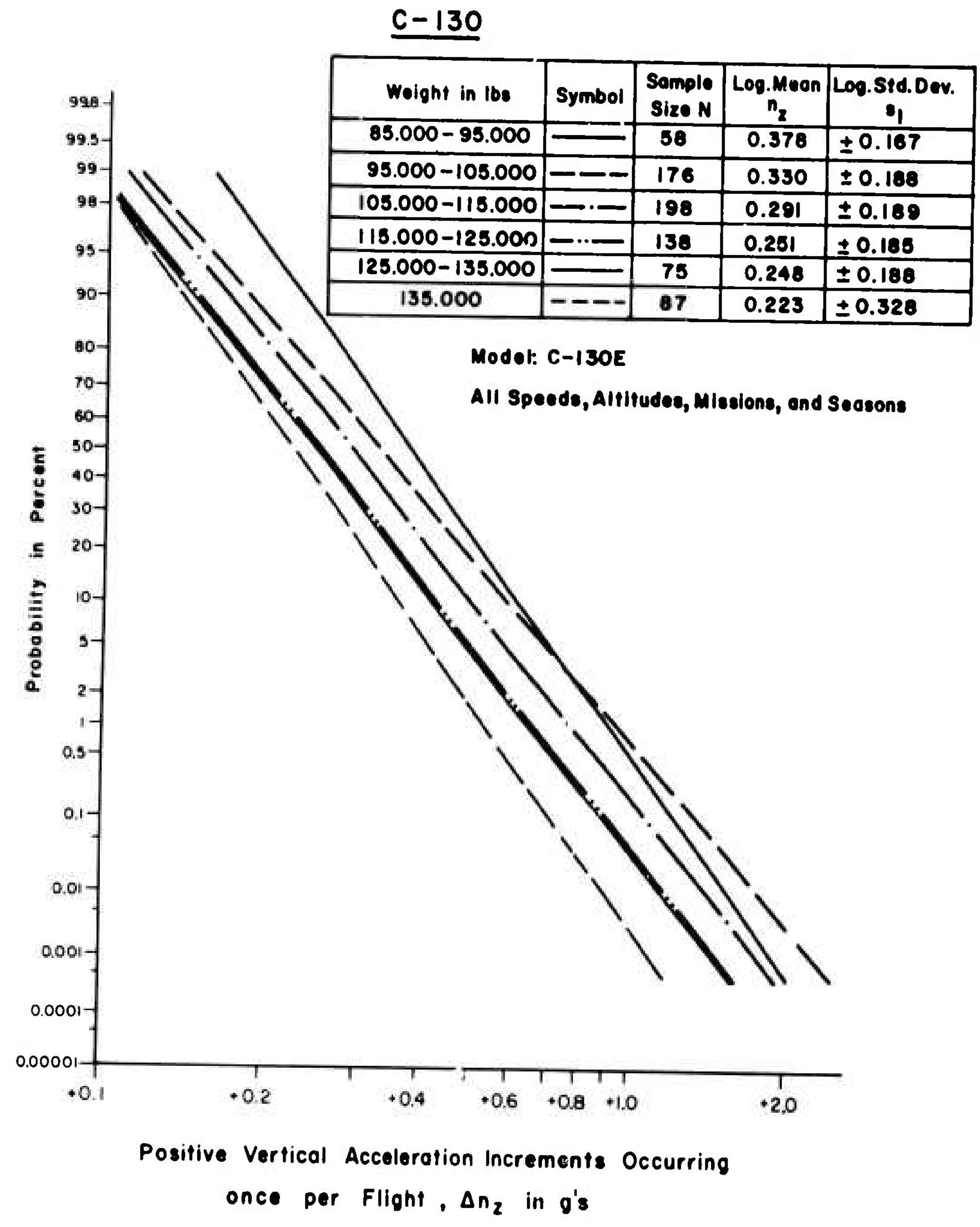
If the original data were not identified by season, the gust velocities are presented only by altitude bands.

Where two seasons determined the same curve, only one curve is drawn and the legend modified to indicate that this occurred. Obvious differences in the data are represented as distinct curves, but as single curves when the data overlap.

The B-58 data are represented in the plots by only two altitudes, although data are available for all altitudes to 40,000 feet. Transfer functions are available only for the two altitudes represented. No attempt was made to extrapolate these data to higher altitudes.

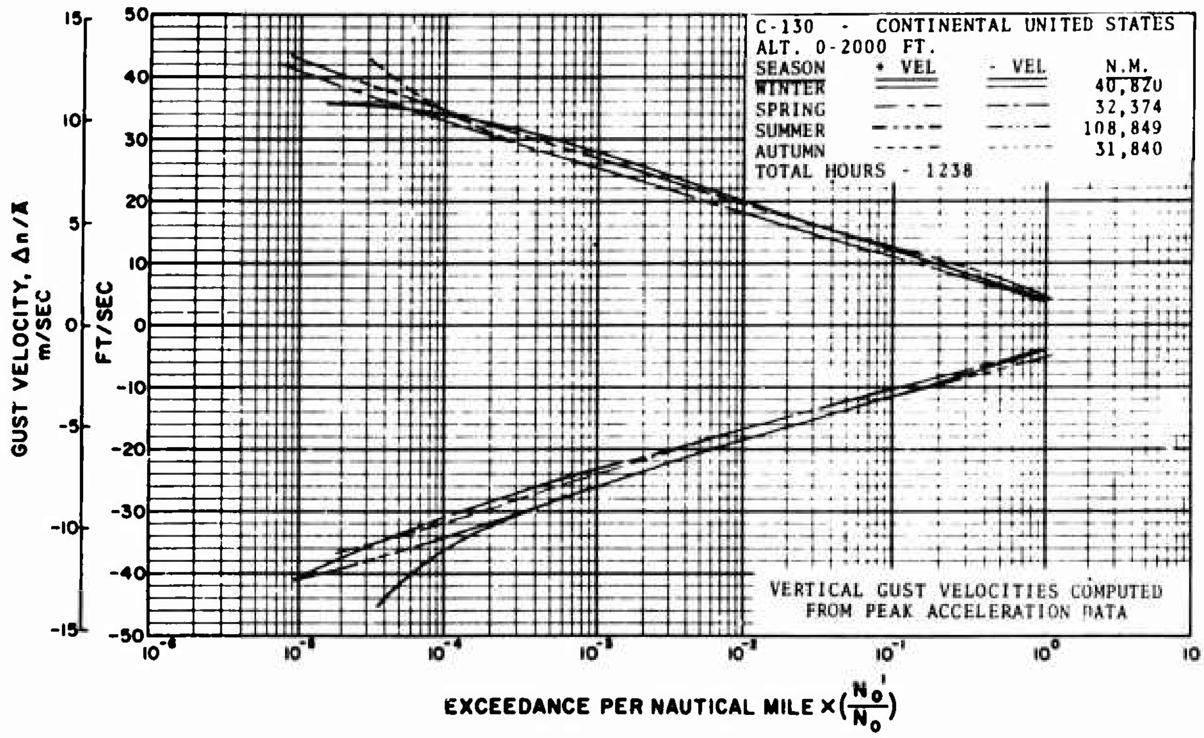
The C-130 data are represented by three sets of data which resulted from earlier decisions. Initially a decision was made not to change any of the initial ranges of airspeed or altitude, and to preserve all of the coincident values of other parameters. Hence the C-130 data recorded from flights flown primarily in the United States could not be combined with Southeast Asia data since the altitude ranges were different. The C-130 data from Southeast Asia could not be combined with those from World-Wide flights because the elevator and flap positions were recorded on the aircraft in one area but not on those in the other.

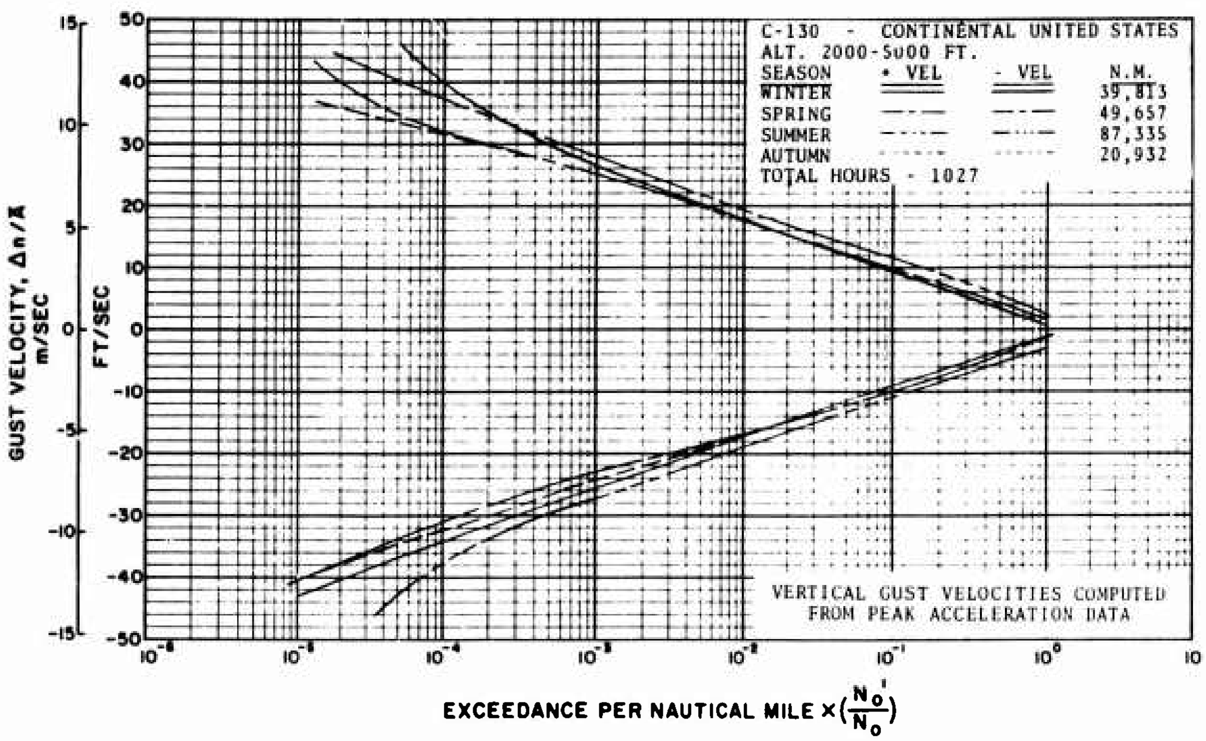
The T-38 and F-4 data are not presented since the threshold of 0.5g in the original data is too great to yield any but the largest values of gust velocity.

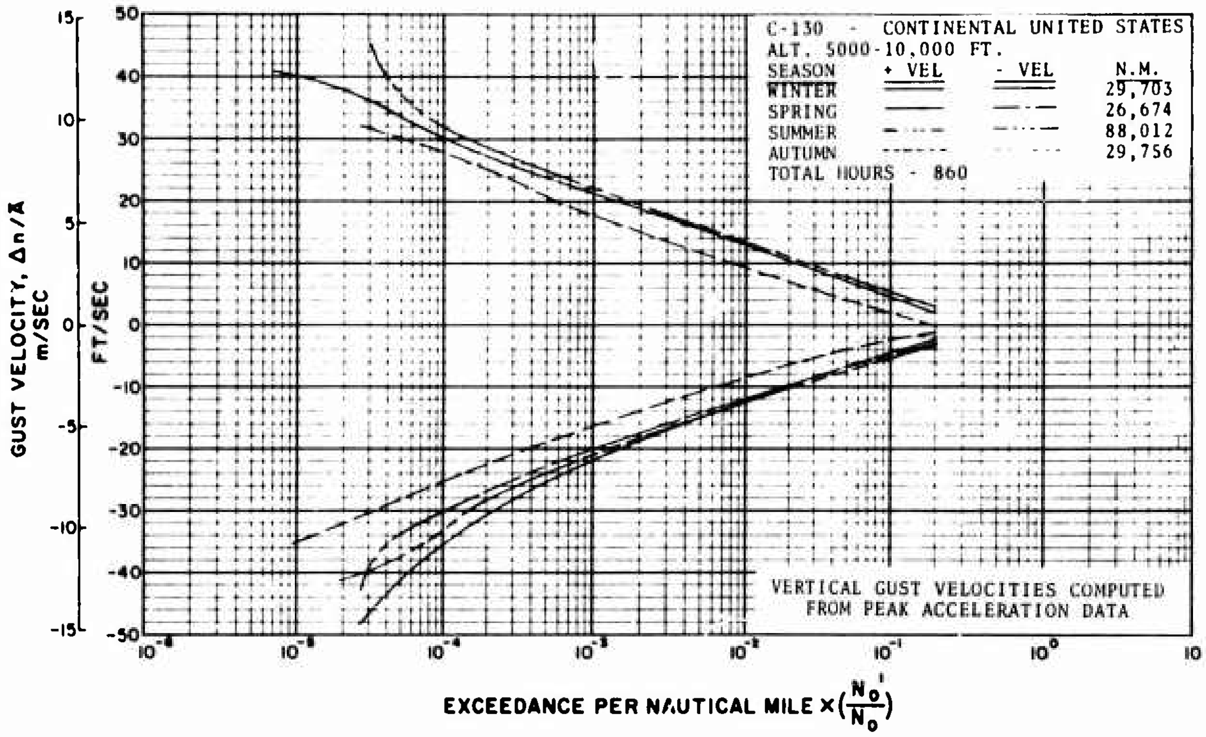


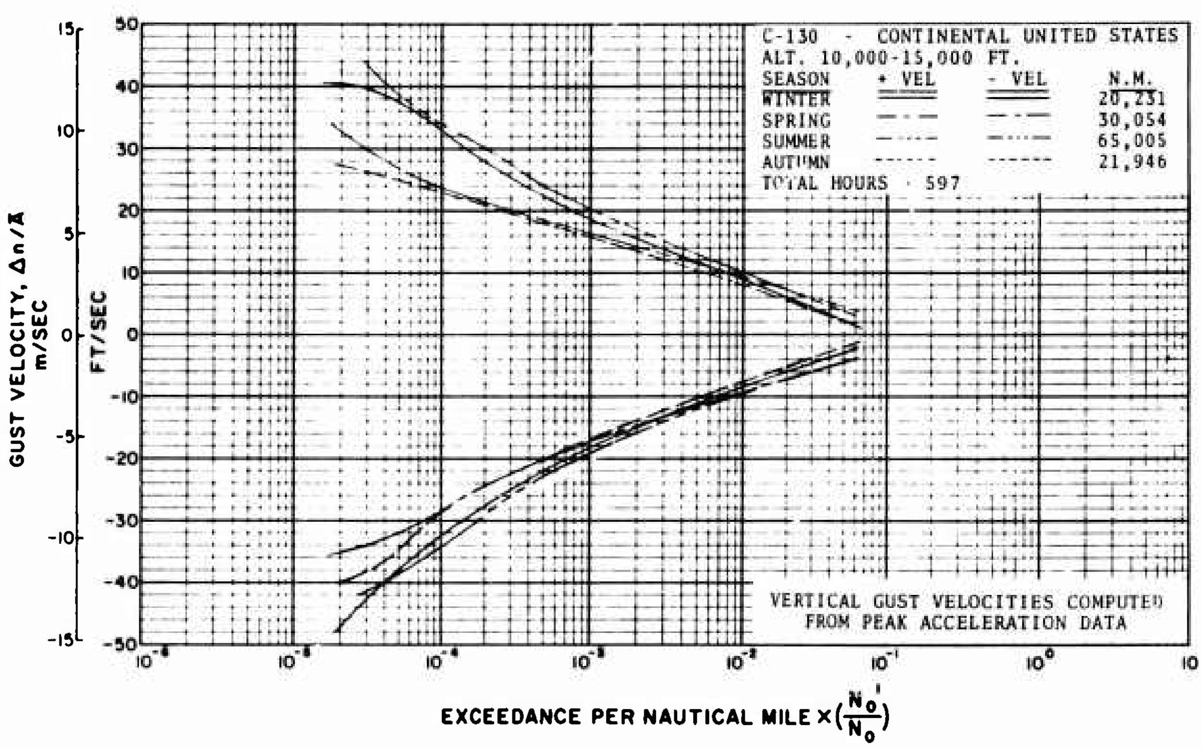
Weight in lbs	Symbol	Sample Size N	Log. Mean n_z	Log. Std. Dev. s_1
85.000 - 95.000	———	58	0.378	± 0.167
95.000 - 105.000	— — —	176	0.330	± 0.188
105.000 - 115.000	—·—	198	0.291	± 0.189
115.000 - 125.000	—··—	138	0.251	± 0.185
125.000 - 135.000	———	75	0.248	± 0.188
135.000	- - - -	87	0.223	± 0.328

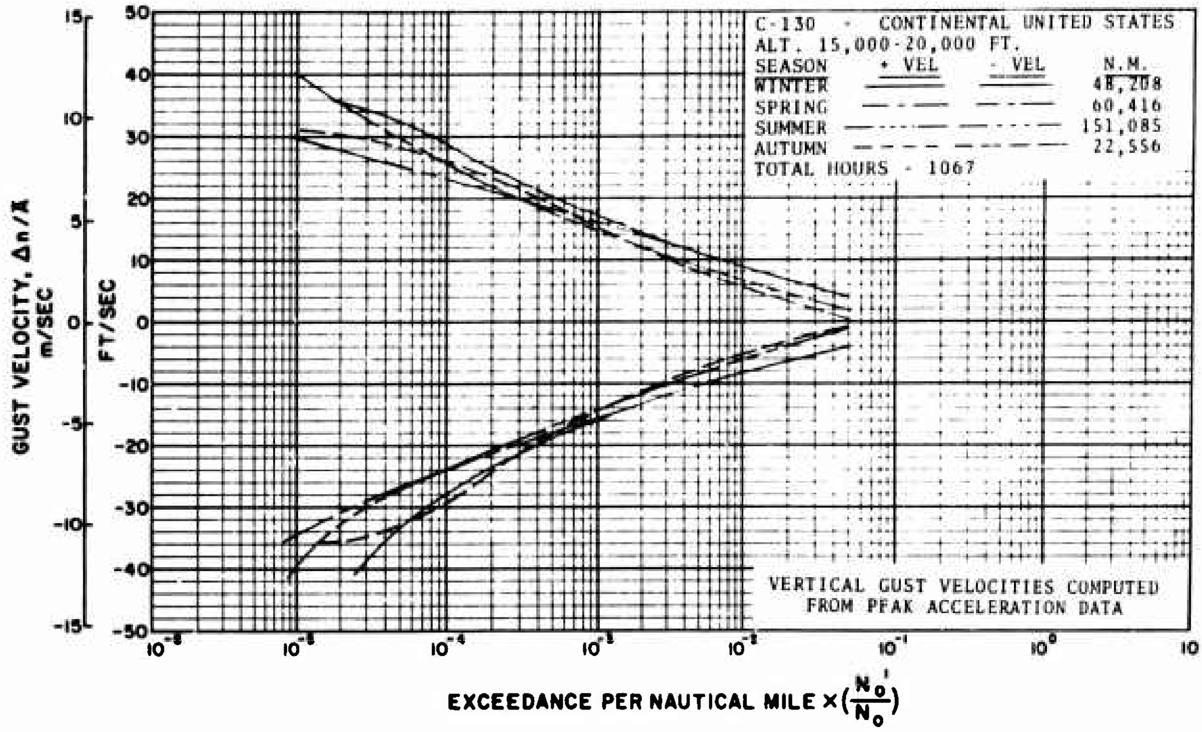
Figure 3-1. Extreme Value Distribution (Log Normal): Effect of Weights

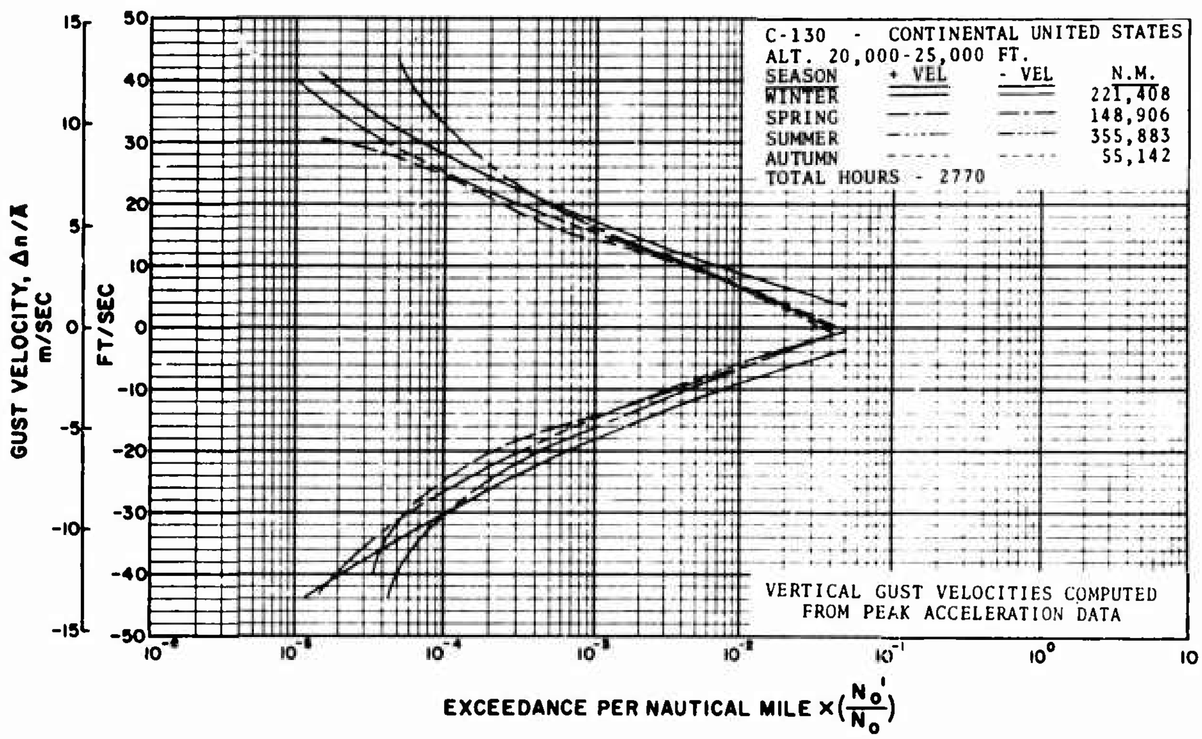

C-130 - CONTINENTAL UNITED STATES
ALT. 0-2000 FT.
SEASON + VEL - VEL N.M.
WINTER 40,820
SPRING 32,374
SUMMER 108,849
AUTUMN 31,840
TOTAL HOURS - 1238
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_o'/N_o)

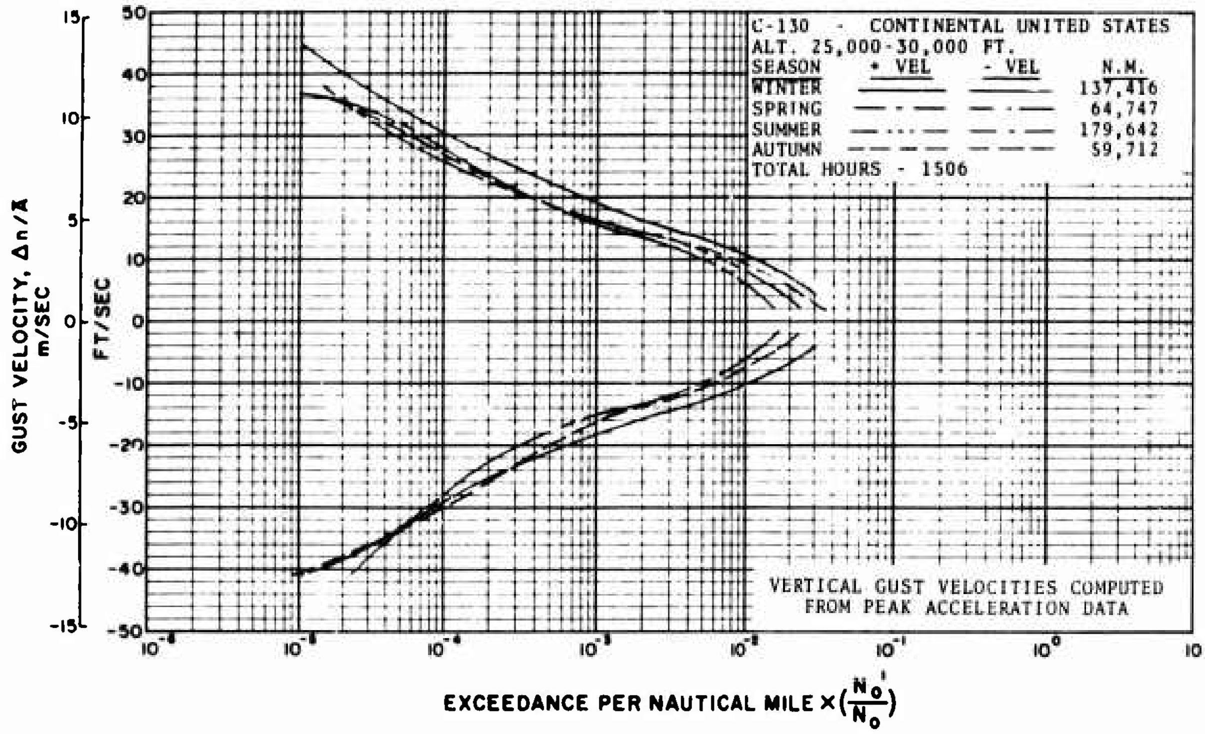

C-130 - CONTINENTAL UNITED STATES
ALT. 2000-5000 FT.
SEASON + VEL - VEL N.M.
WINTER 39,813
SPRING 49,657
SUMMER 87,335
AUTUMN 20,932
TOTAL HOURS - 1027
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_o'/N_o)

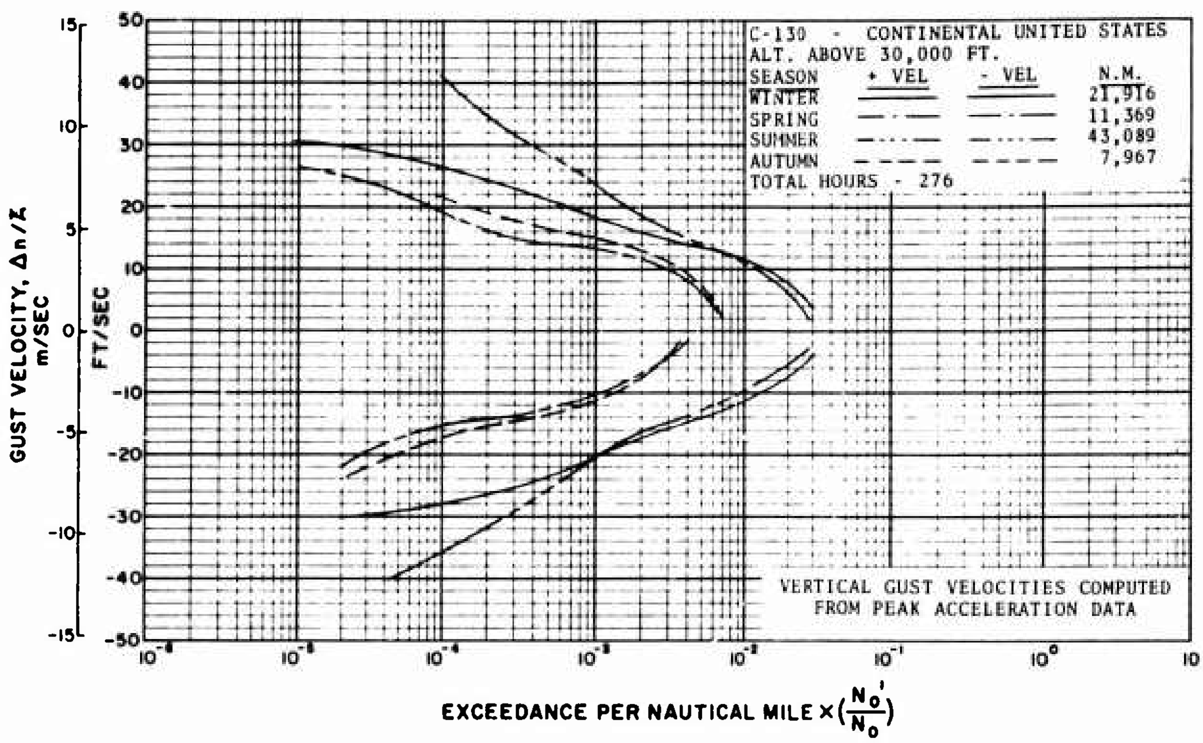

C-130 - CONTINENTAL UNITED STATES
ALT. 5000-10,000 FT.
SEASON + VEL - VEL N.M.
WINTER 29,703
SPRING 26,674
SUMMER 88,012
AUTUMN 29,756
TOTAL HOURS - 860
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_o'}{N_o}$)

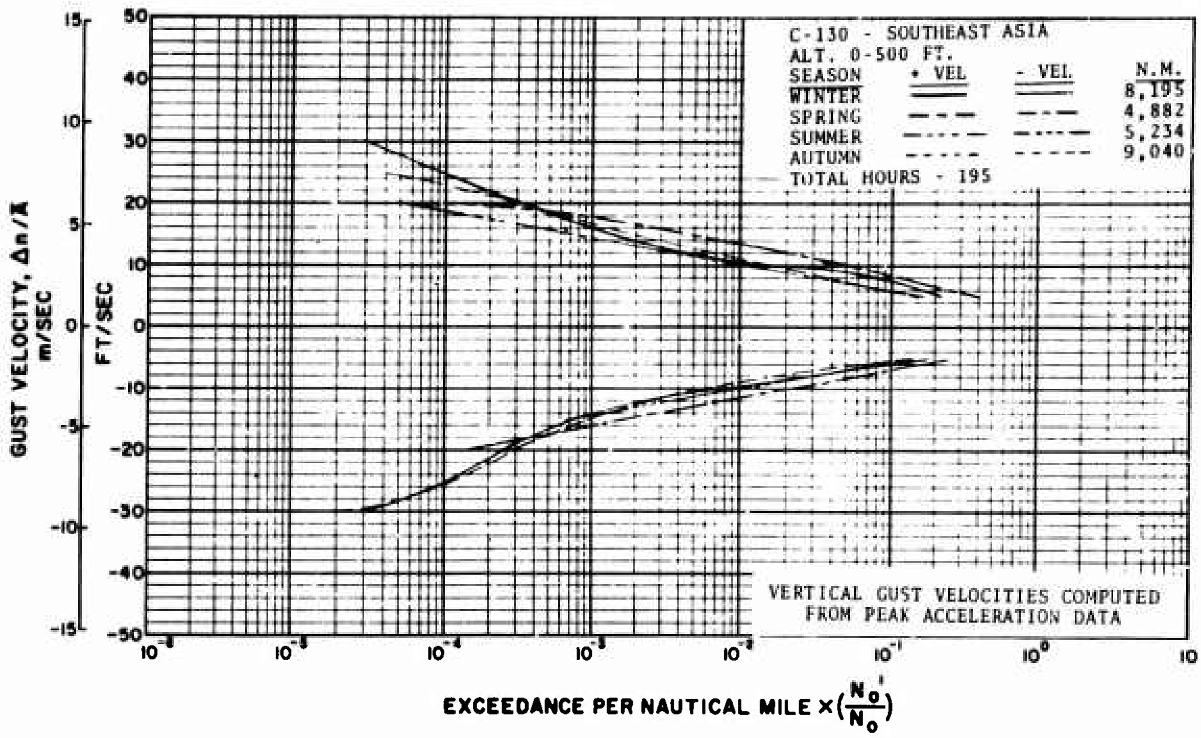

C-130 - CONTINENTAL UNITED STATES
ALT. 10,000-15,000 FT.
SEASON + VEL - VEL N.M.
WINTER 20,231
SPRING 30,054
SUMMER 65,005
AUTUMN 21,946
TOTAL HOURS - 597
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_o'}{N_o}$)

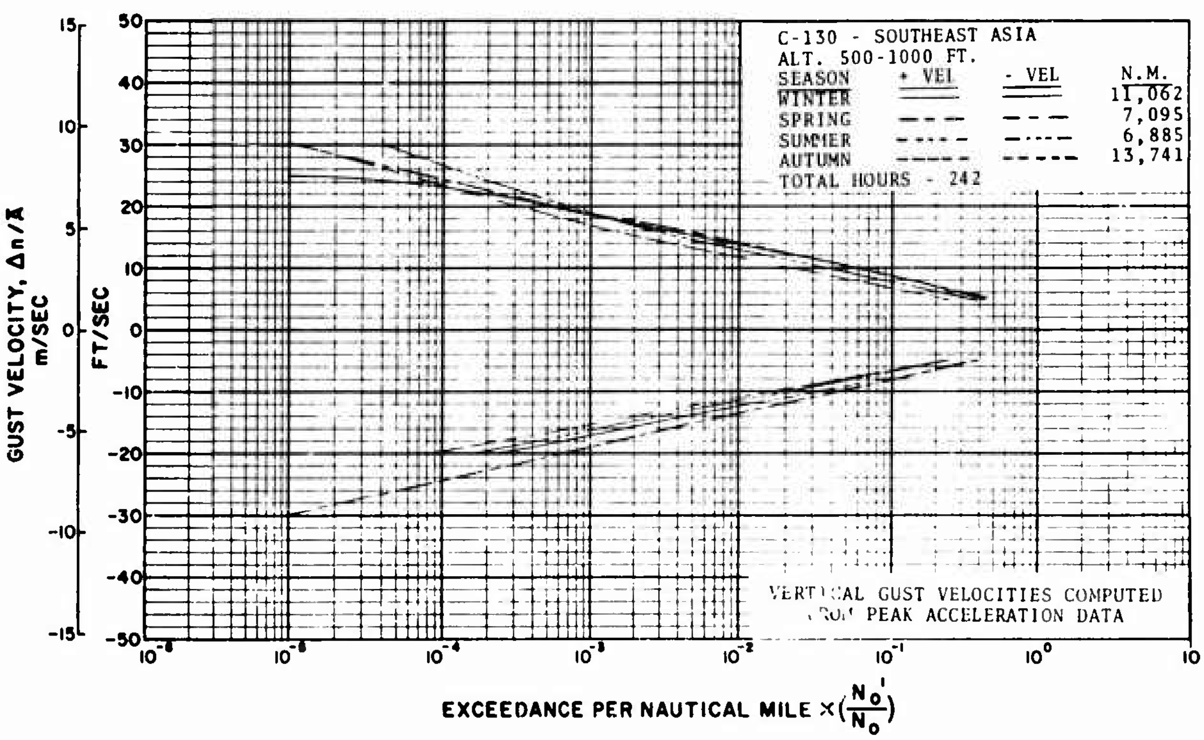

C-130 - CONTINENTAL UNITED STATES
ALT. 15,000-20,000 FT.
SEASON + VEL - VEL N.M.
WINTER 48,208
SPRING 60,416
SUMMER 151,085
AUTUMN 22,556
TOTAL HOURS - 1067
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE ×(N_o'/N_o)

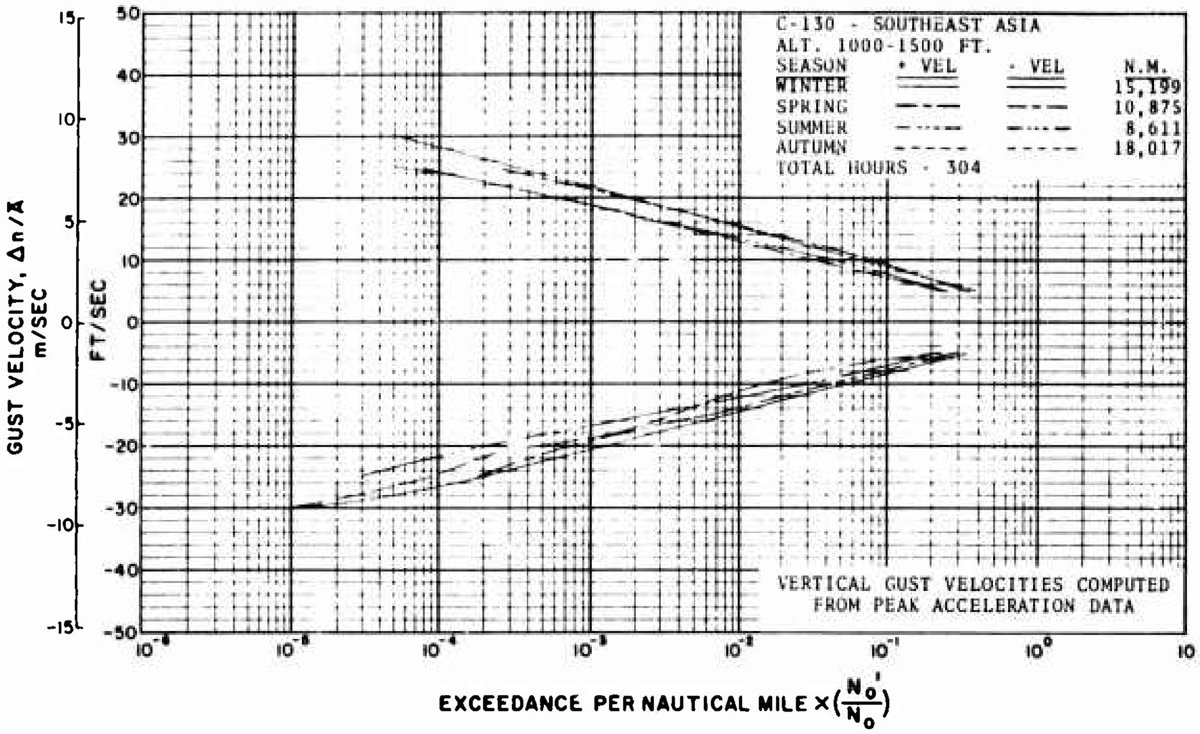

C-130 - CONTINENTAL UNITED STATES
ALT. 20,000-25,000 FT.
SEASON + VEL - VEL N.M.
WINTER 221,408
SPRING 148,906
SUMMER 355,883
AUTUMN 55,142
TOTAL HOURS - 2770
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE ×(N_o'/N_o)

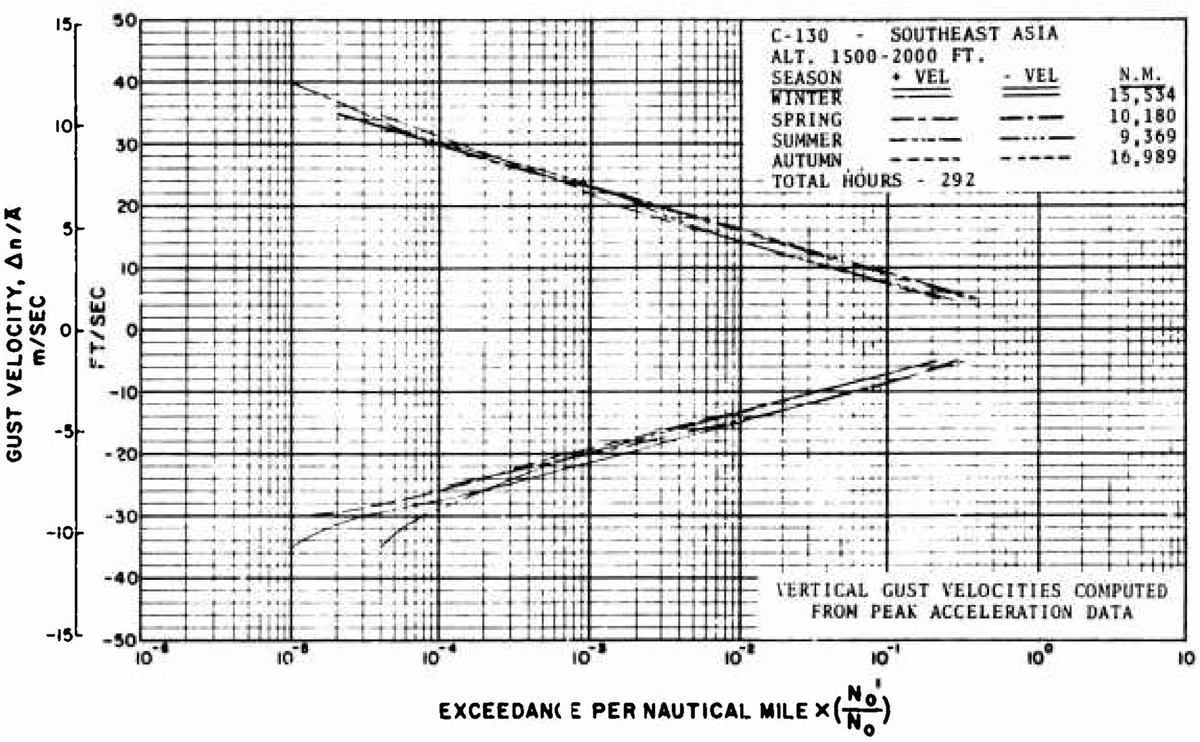

C-130 - CONTINENTAL UNITED STATES
ALT. 25,000-30,000 FT.
SEASON + VEL - VEL N.M.
WINTER 137,416
SPRING 64,747
SUMMER 179,642
AUTUMN 59,712
TOTAL HOURS - 1506
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/K m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

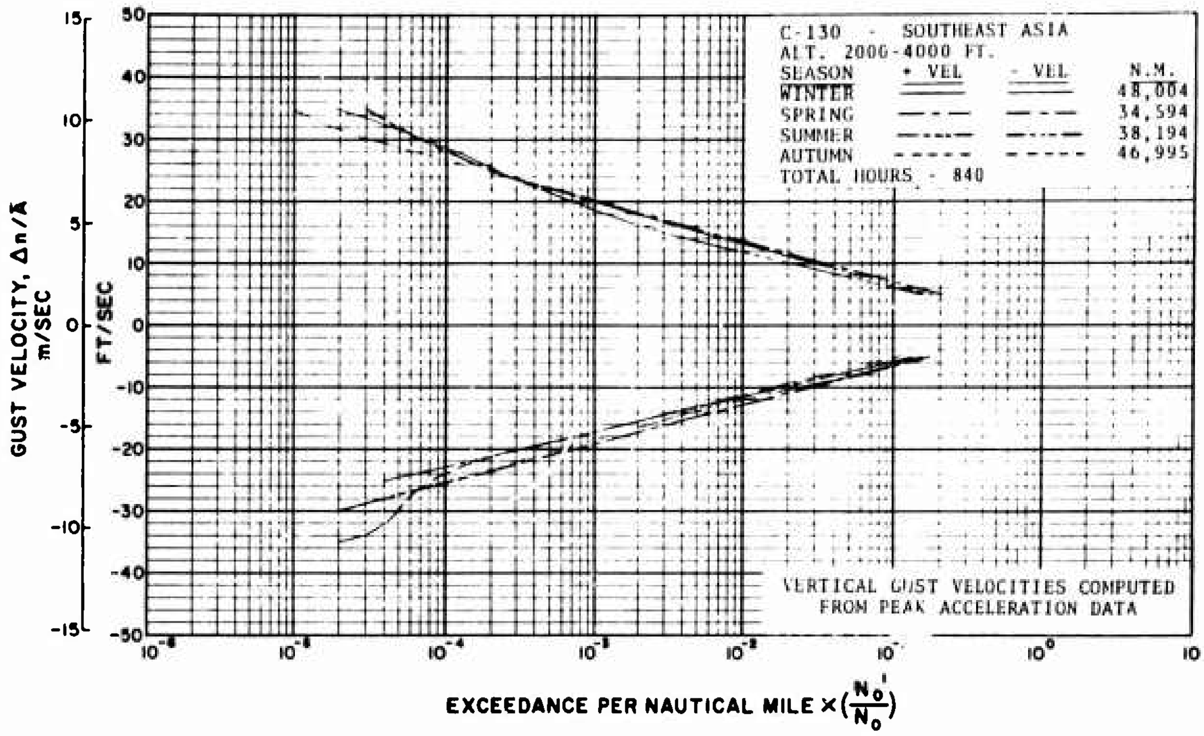

C-130 - CONTINENTAL UNITED STATES
ALT. ABOVE 30,000 FT.
SEASON + VEL - VEL N.M.
WINTER 21,916
SPRING 11,369
SUMMER 43,089
AUTUMN 7,967
TOTAL HOURS - 276
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/K m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

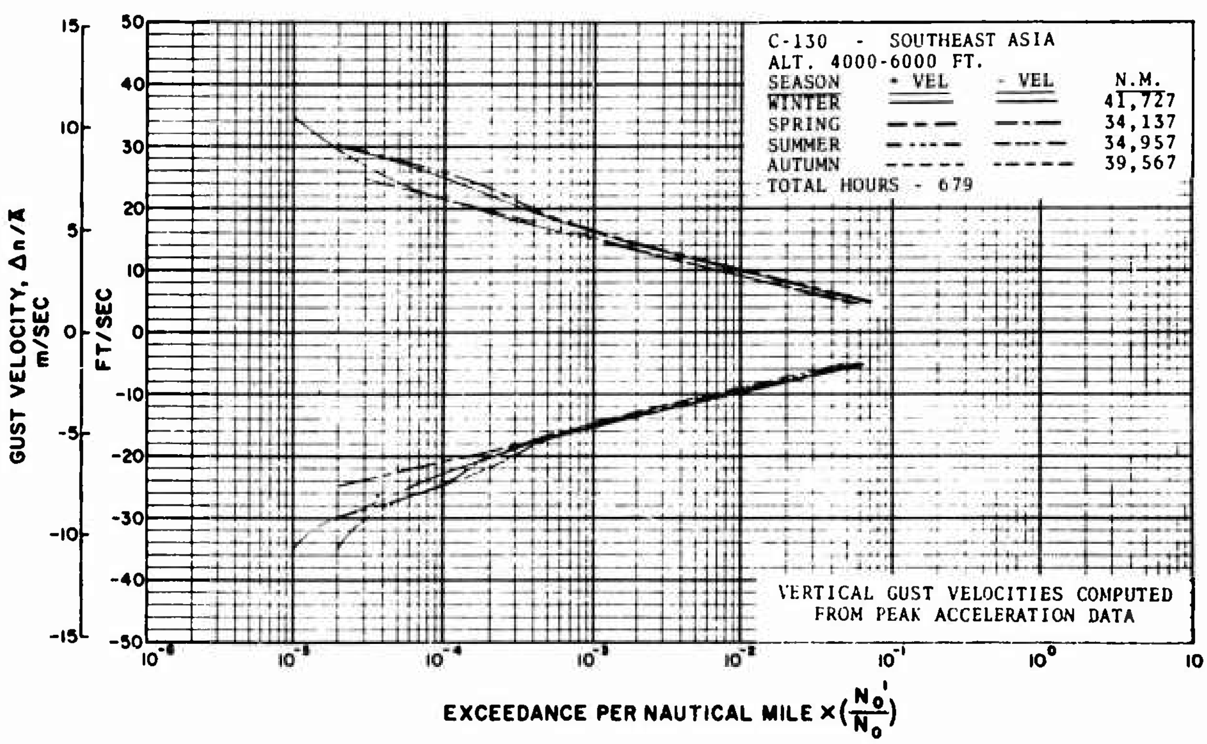

C-130 - SOUTHEAST ASIA
ALT. 0-500 FT.
SEASON + VEL - VEL N.M.
WINTER 8,195
SPRING 4,882
SUMMER 5,234
AUTUMN 9,040
TOTAL HOURS - 195
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE ×($\frac{N_0'}{N_0}$)

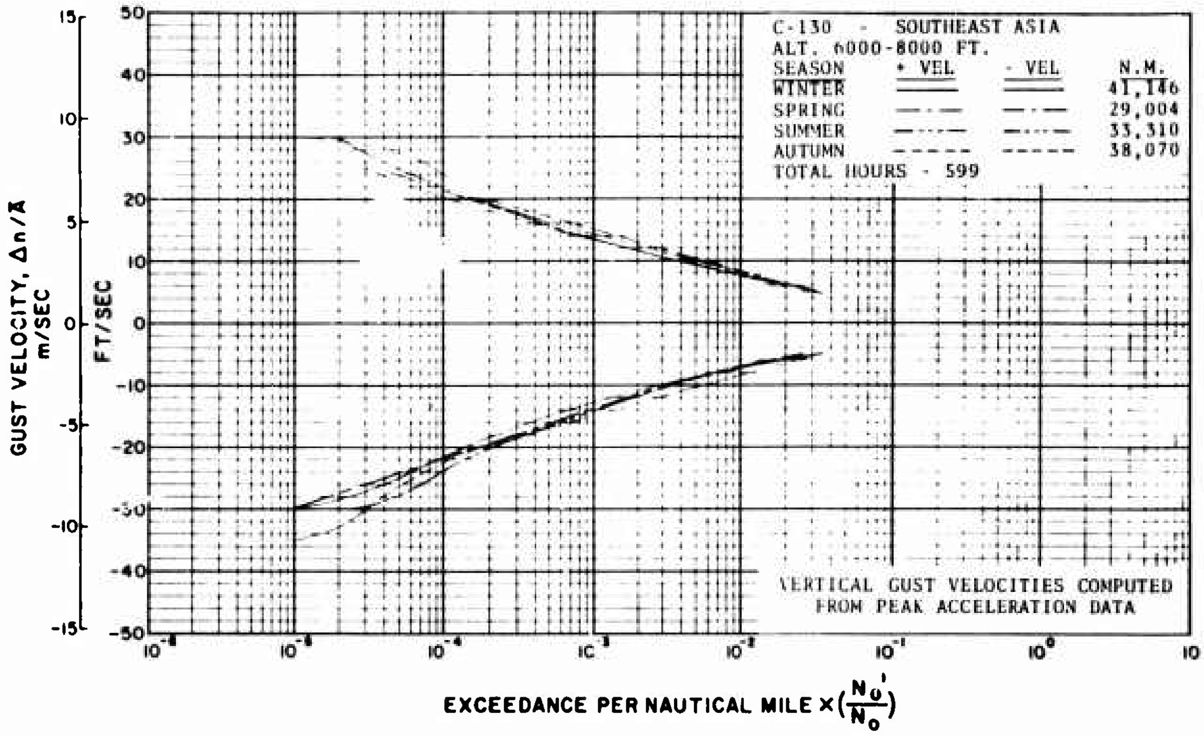

C-130 - SOUTHEAST ASIA
ALT. 500-1000 FT.
SEASON + VEL - VEL N.M.
WINTER 11,062
SPRING 7,095
SUMMER 6,885
AUTUMN 13,741
TOTAL HOURS - 242
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE ×($\frac{N_0'}{N_0}$)

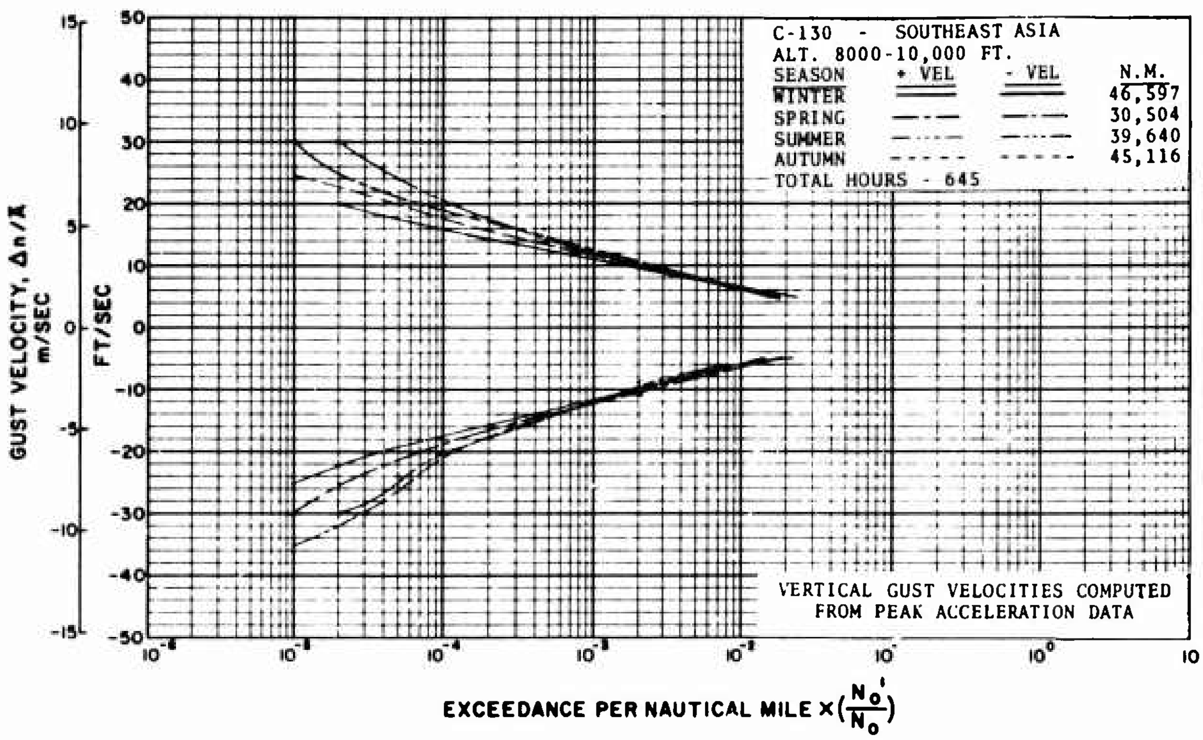

C-130 - SOUTHEAST ASIA
ALT. 1000-1500 FT.
SEASON + VEL - VEL N.M.
WINTER 15,199
SPRING 10,875
SUMMER 8,611
AUTUMN 18,017
TOTAL HOURS - 304
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

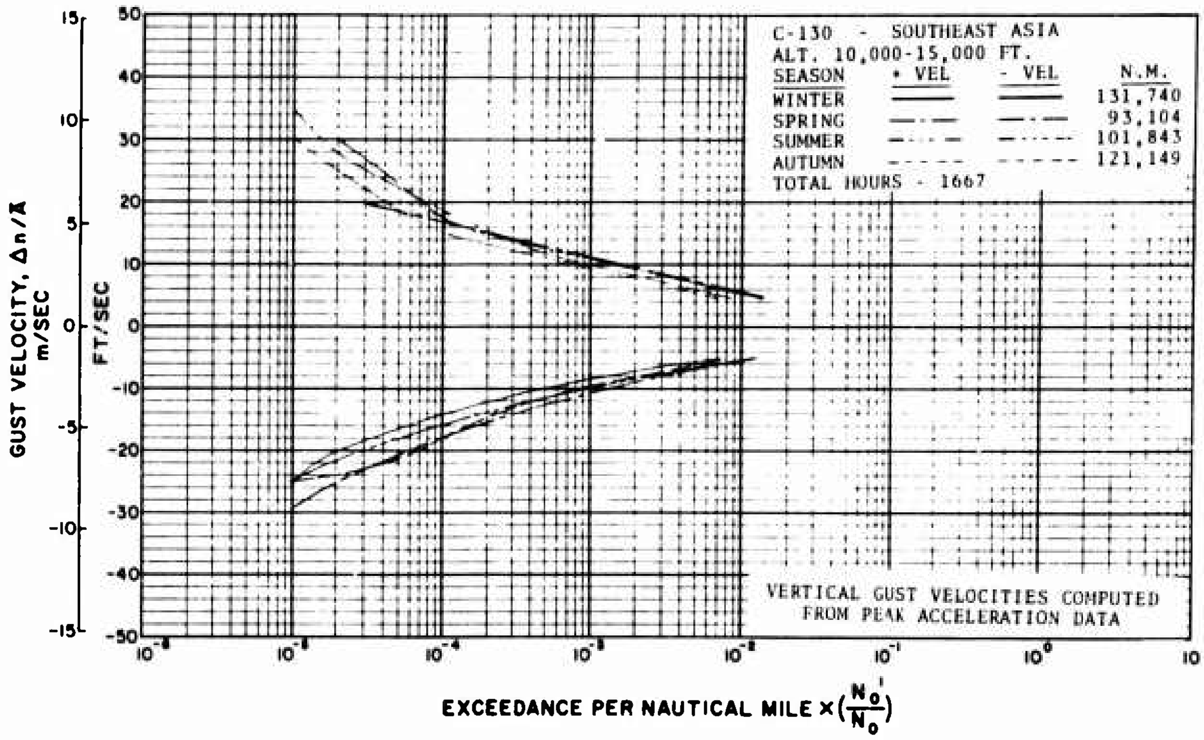

C-130 - SOUTHEAST ASIA
ALT. 1500-2000 FT.
SEASON + VEL - VEL N.M.
WINTER 15,534
SPRING 10,180
SUMMER 9,369
AUTUMN 16,989
TOTAL HOURS - 292
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

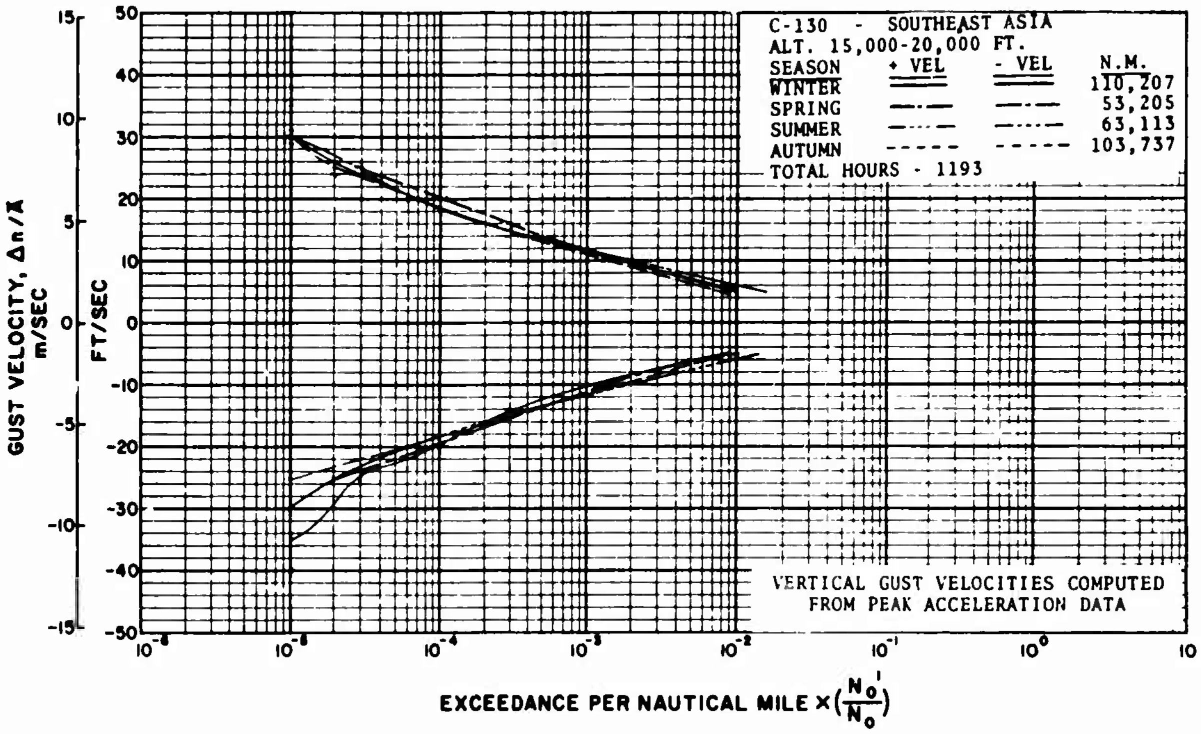

C-130 - SOUTHEAST ASIA
ALT. 2000-4000 FT.
SEASON + VEL - VEL N.M.
WINTER 48,004
SPRING 34,594
SUMMER 38,194
AUTUMN 46,995
TOTAL HOURS - 840
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

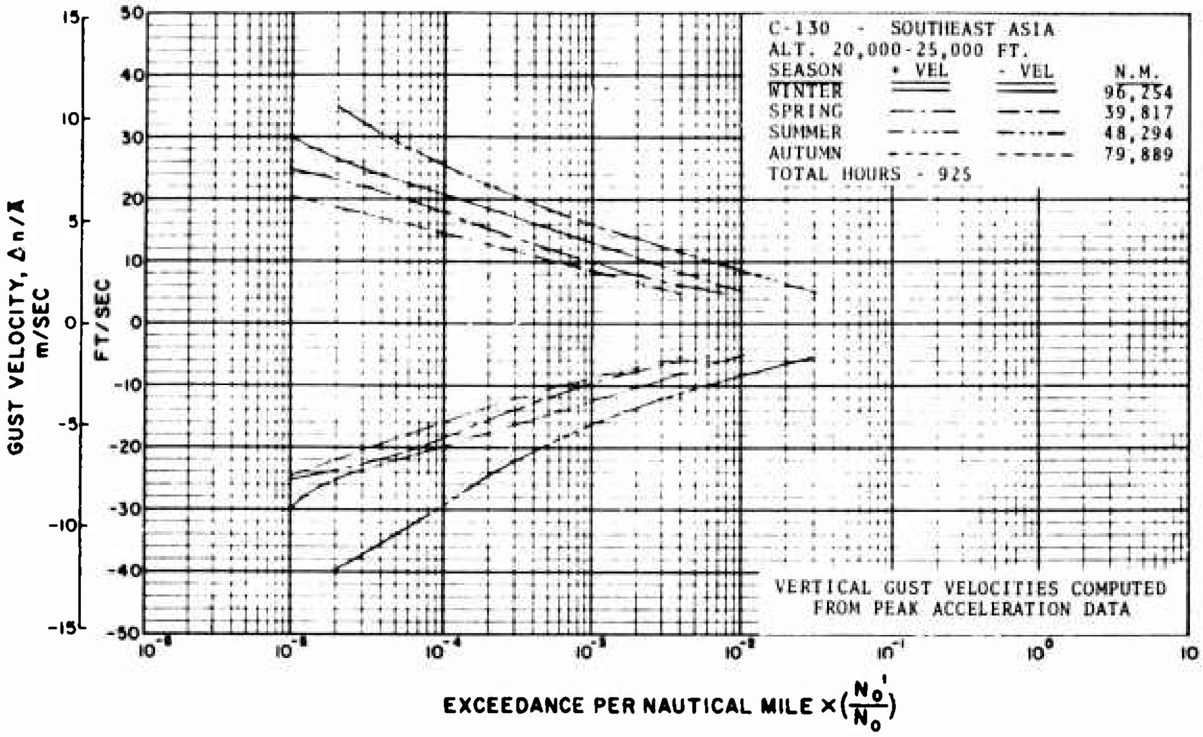

C-130 - SOUTHEAST ASIA
ALT. 4000-6000 FT.
SEASON + VEL - VEL N.M.
WINTER 41,727
SPRING 34,137
SUMMER 34,957
AUTUMN 39,567
TOTAL HOURS - 679
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)


C-130 - SOUTHEAST ASIA
ALT. 6000-8000 FT.
SEASON + VEL - VEL N.M.
WINTER 41,146
SPRING 29,004
SUMMER 33,310
AUTUMN 38,070
TOTAL HOURS - 599
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

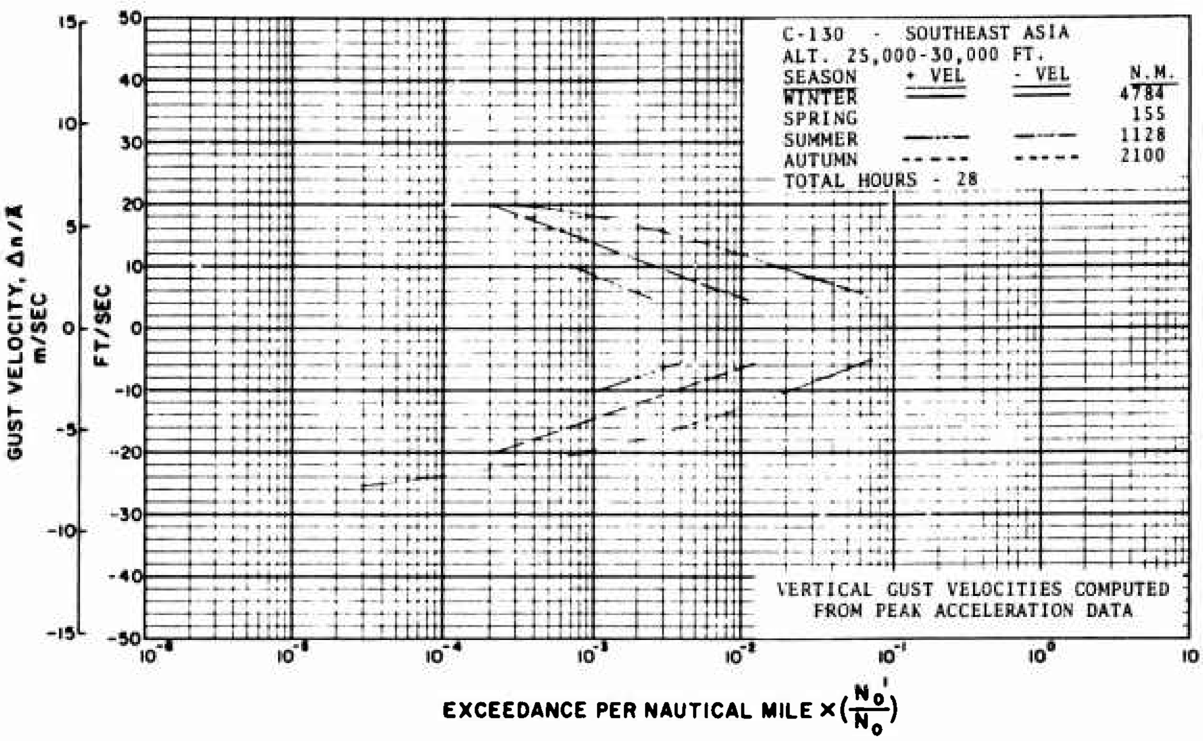

C-130 - SOUTHEAST ASIA
ALT. 8000-10,000 FT.
SEASON + VEL - VEL N.M.
WINTER 46,597
SPRING 30,504
SUMMER 39,640
AUTUMN 45,116
TOTAL HOURS - 645
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)


C-130 - SOUTHEAST ASIA
ALT. 10,000-15,000 FT.
SEASON + VEL - VEL N.M.
WINTER 131,740
SPRING 93,104
SUMMER 101,843
AUTUMN 121,149
TOTAL HOURS - 1667
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

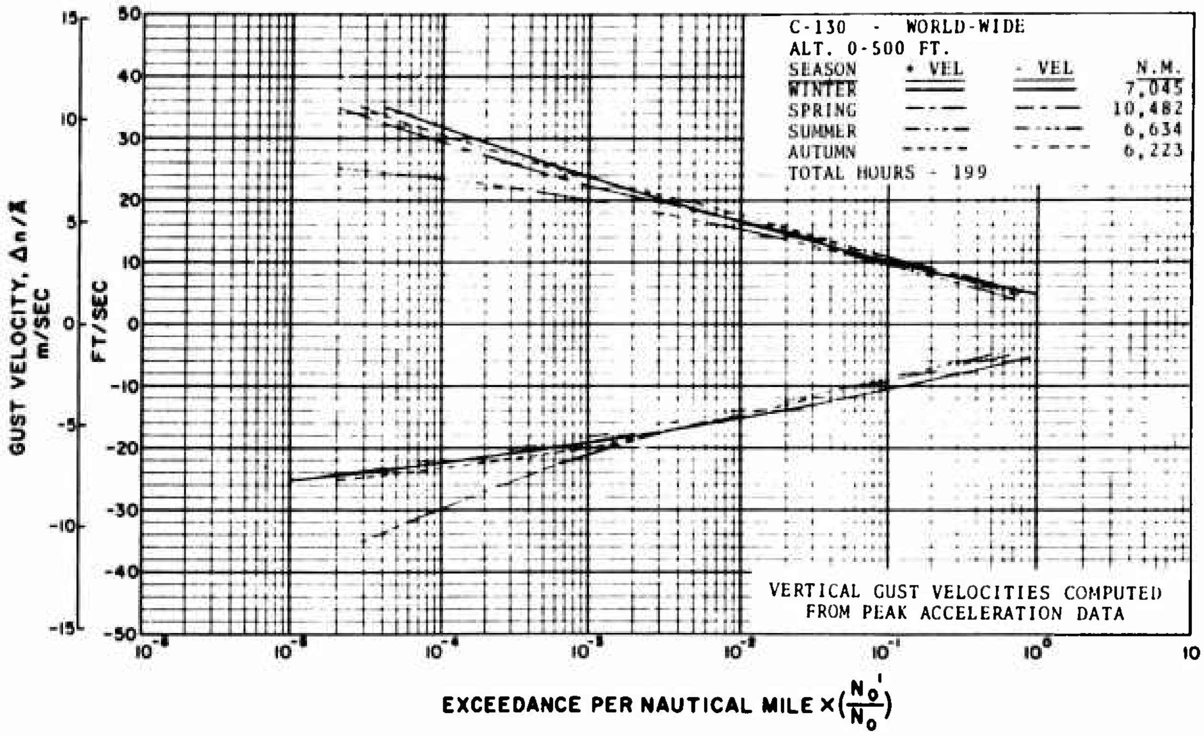

C-130 - SOUTHEAST ASIA
ALT. 15,000-20,000 FT.
SEASON + VEL - VEL N.M.
WINTER 110,207
SPRING 53,205
SUMMER 63,113
AUTUMN 103,737
TOTAL HOURS - 1193
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

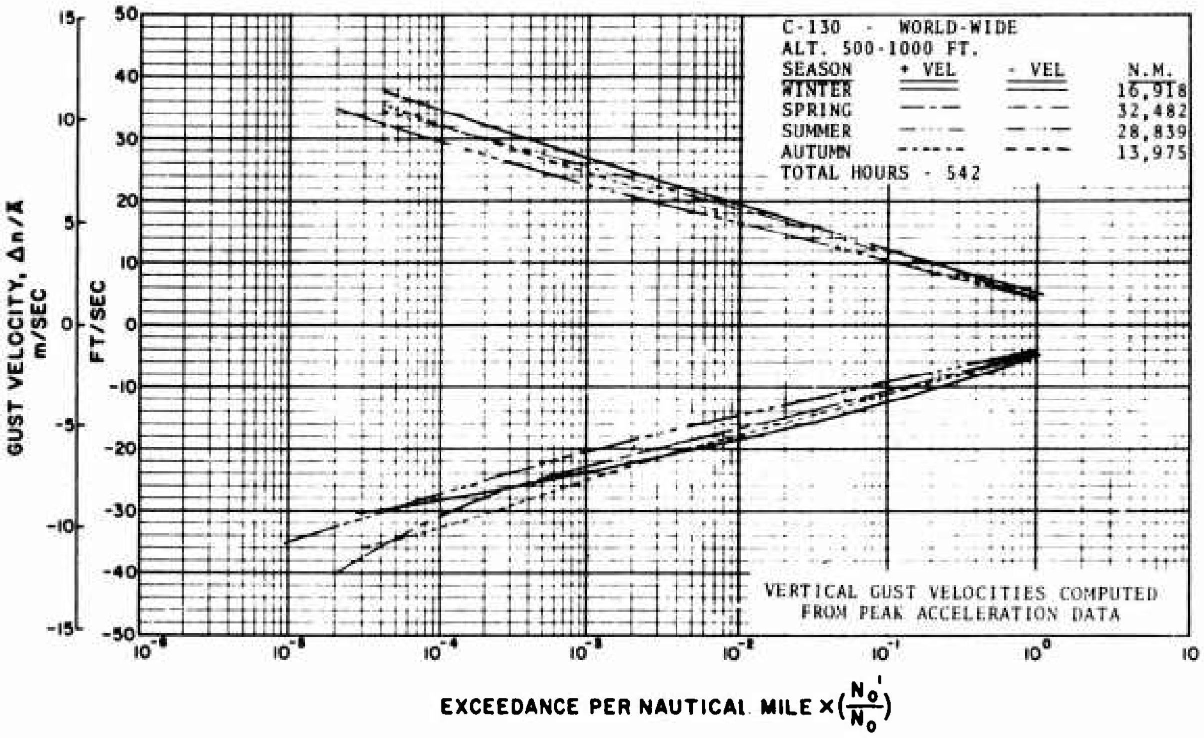


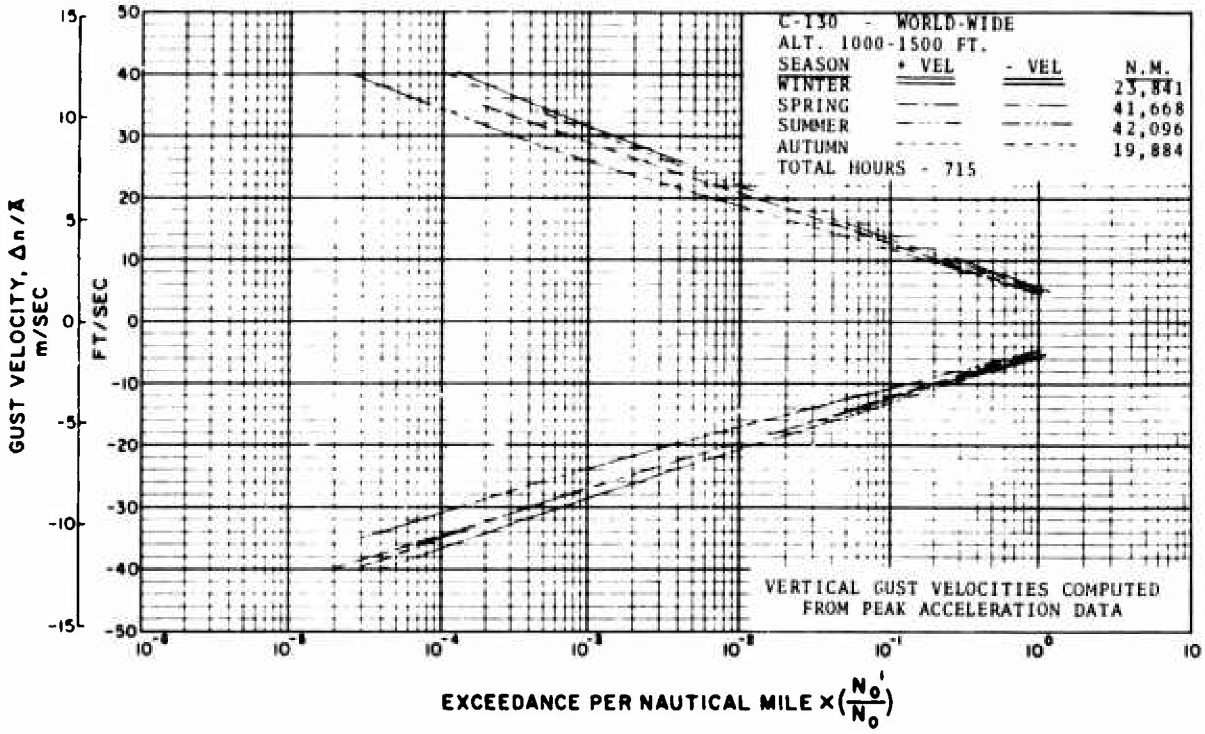
C-130 - SOUTHEAST ASIA
ALT. 20,000-25,000 FT.
SEASON + VEL - VEL N.M.
WINTER 96,254
SPRING 39,817
SUMMER 48,294
AUTUMN 79,889
TOTAL HOURS - 925
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

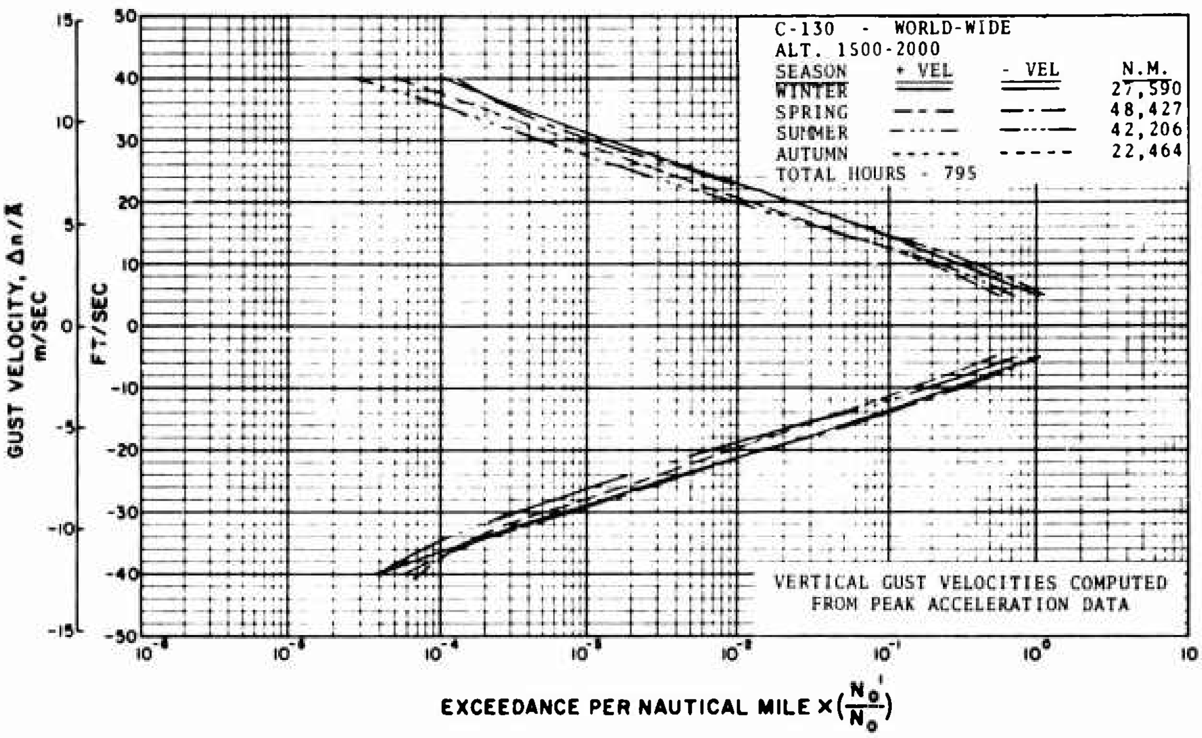


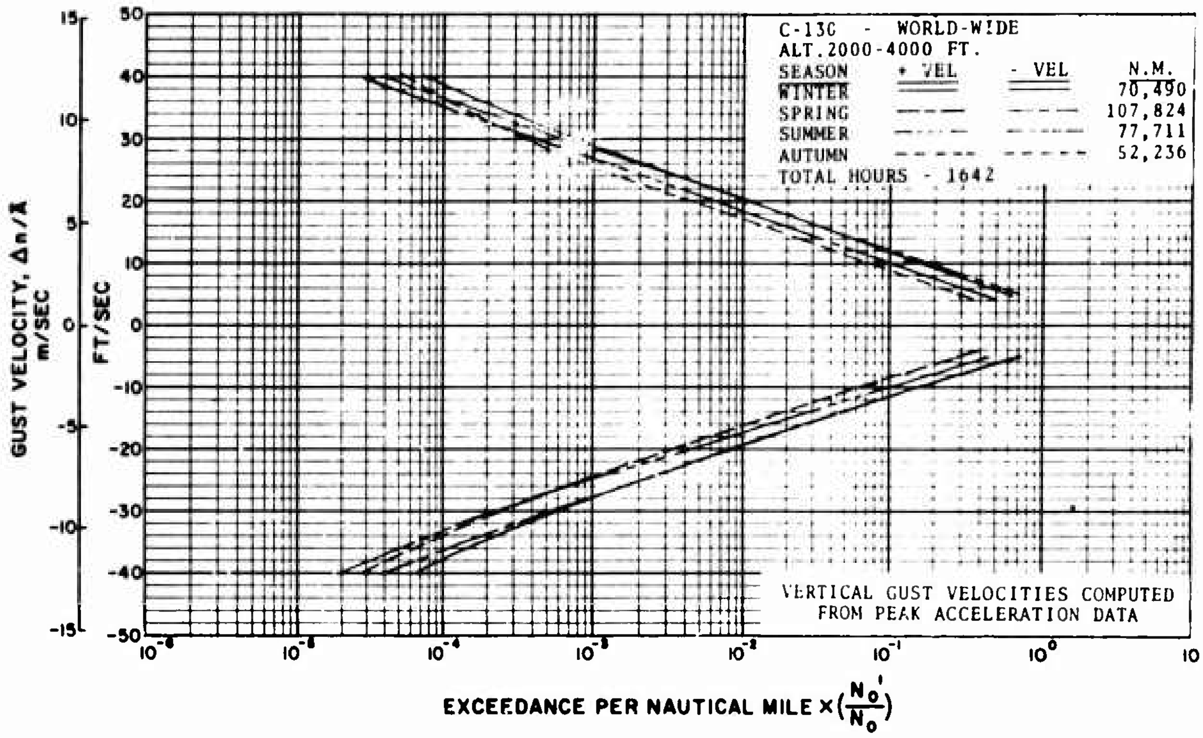
C-130 - SOUTHEAST ASIA
ALT. 25,000-30,000 FT.
SEASON + VEL - VEL N.M.
WINTER 4784
SPRING 155
SUMMER 1128
AUTUMN 2100
TOTAL HOURS - 28
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

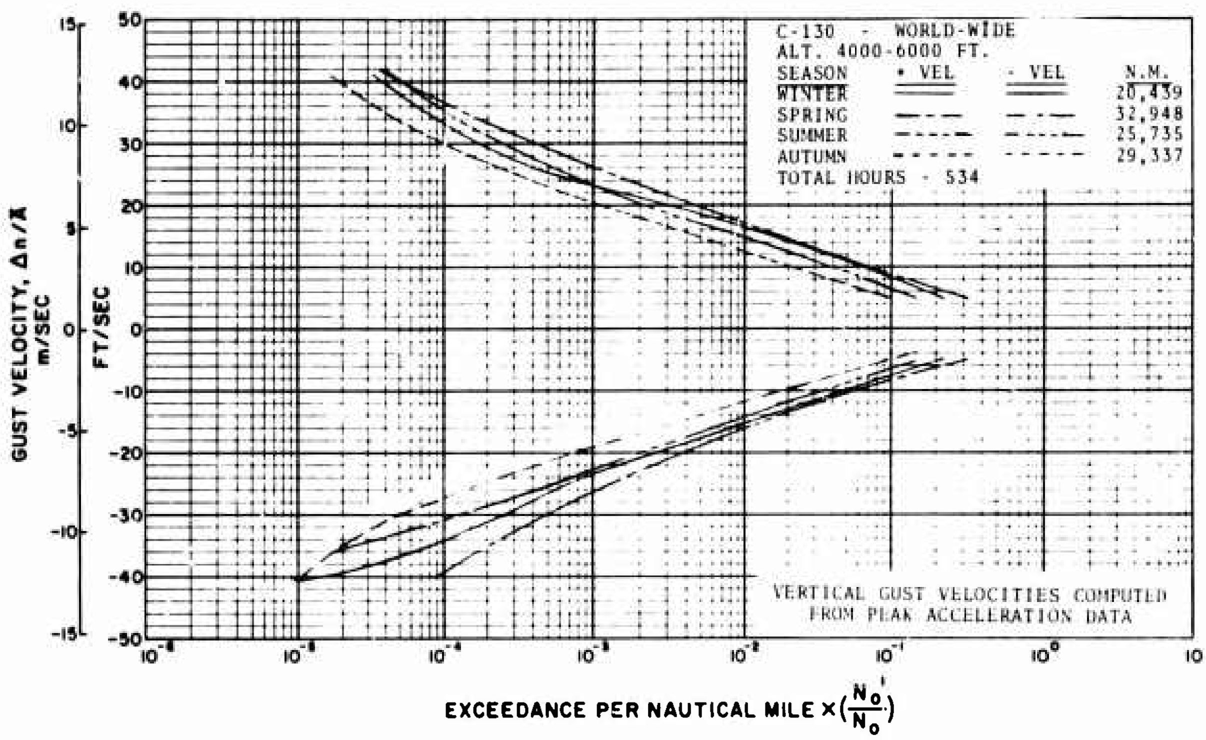

C-130 - WORLD-WIDE
ALT. 0-500 FT.
SEASON + VEL - VEL N.M.
WINTER 7,045
SPRING 10,482
SUMMER 6,634
AUTUMN 6,223
TOTAL HOURS - 199
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/λ m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

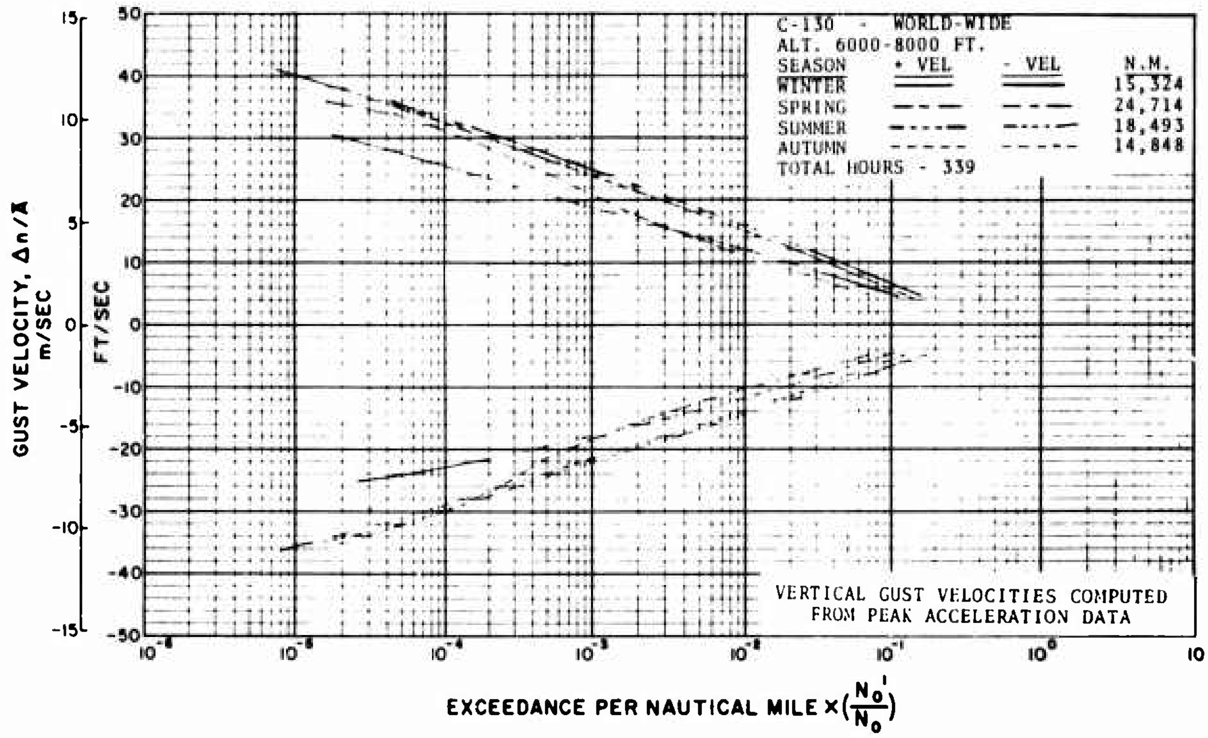

C-130 - WORLD-WIDE
ALT. 500-1000 FT.
SEASON + VEL - VEL N.M.
WINTER 16,918
SPRING 32,482
SUMMER 28,839
AUTUMN 13,975
TOTAL HOURS - 542
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/λ m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

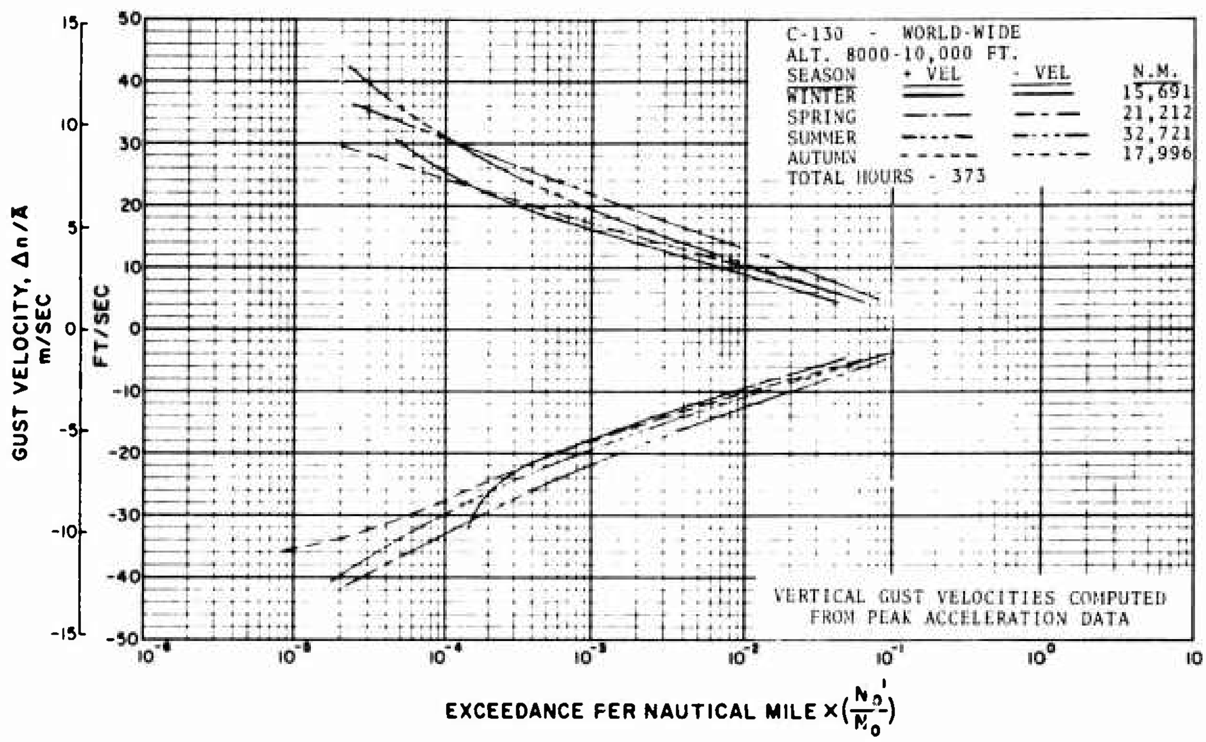

C-130 - WORLD-WIDE
ALT. 1000-1500 FT.
SEASON + VEL - VEL N.M.
WINTER 23,841
SPRING 41,668
SUMMER 42,096
AUTUMN 19,884
TOTAL HOURS - 715
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

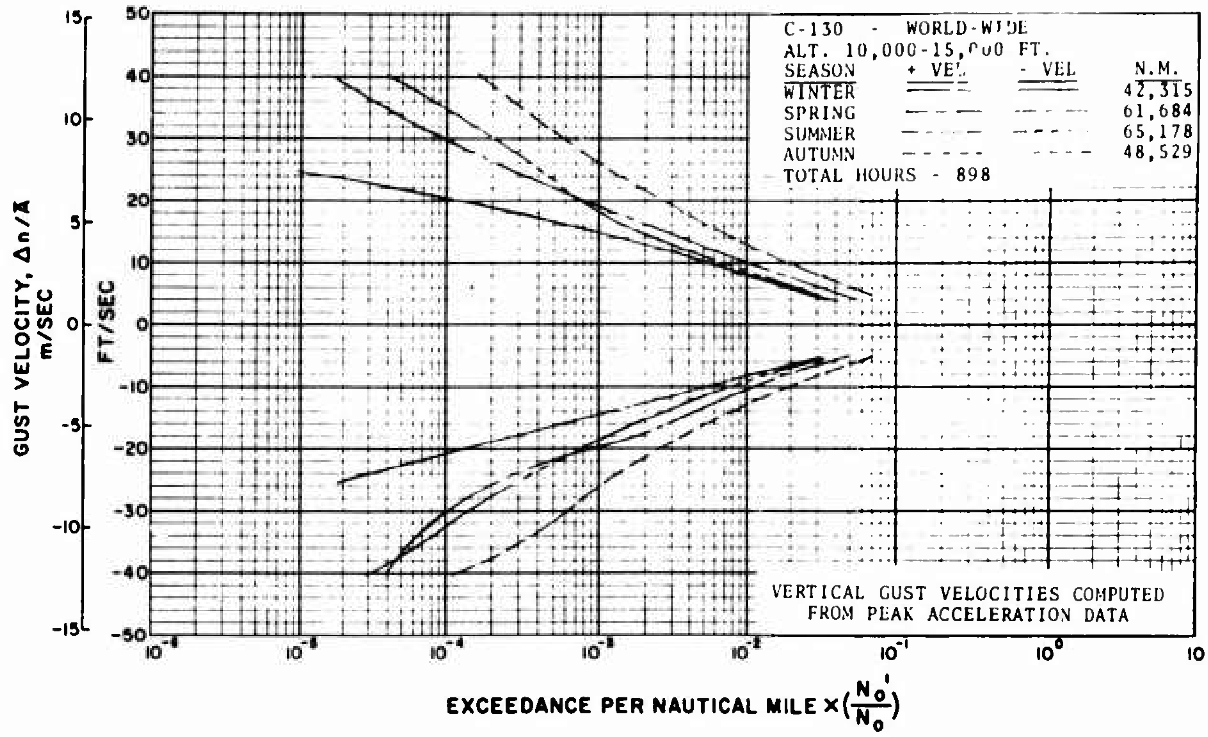

C-130 - WORLD-WIDE
ALT. 1500-2000
SEASON + VEL - VEL N.M.
WINTER 27,590
SPRING 48,427
SUMMER 42,206
AUTUMN 22,464
TOTAL HOURS - 795
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

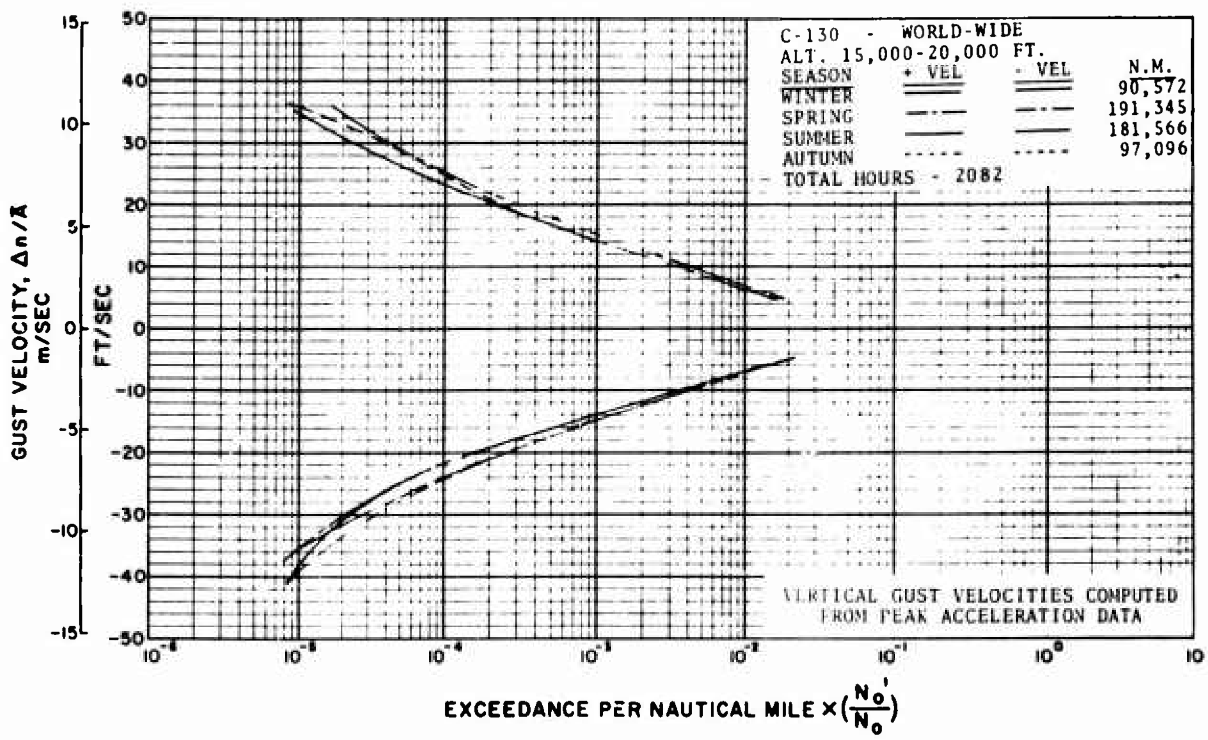

C-130 - WORLD-WIDE
ALT.2000-4000 FT.
SEASON + VEL - VEL N.M.
WINTER 70,490
SPRING 107,824
SUMMER 77,711
AUTUMN 52,236
TOTAL HOURS - 1642
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_o'/N_o)

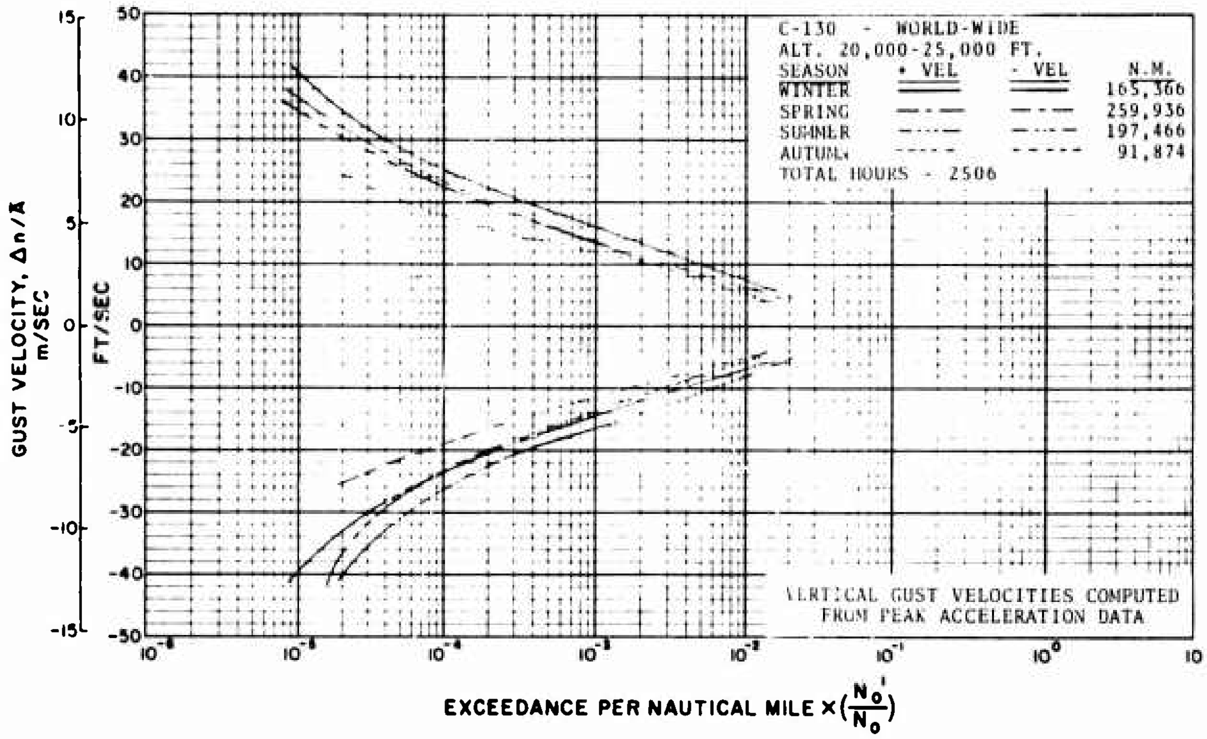

C-130 - WORLD-WIDE
ALT. 4000-6000 FT.
SEASON + VEL - VEL N.M.
WINTER 20,439
SPRING 32,948
SUMMER 25,735
AUTUMN 29,337
TOTAL HOURS - 534
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_o'/N_o)

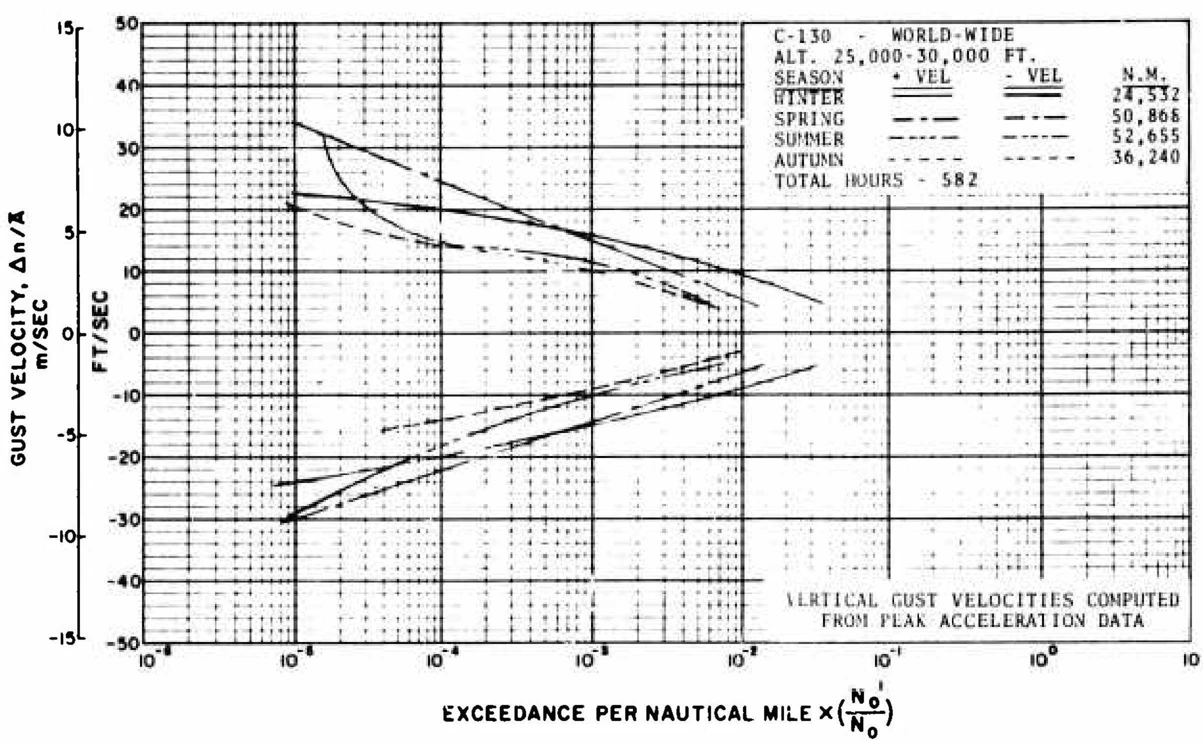

C-130 - WORLD-WIDE
ALT. 6000-8000 FT.
SEASON + VEL - VEL N.M.
WINTER 15,324
SPRING 24,714
SUMMER 18,493
AUTUMN 14,848
TOTAL HOURS - 339
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_o'}{N_o}$)

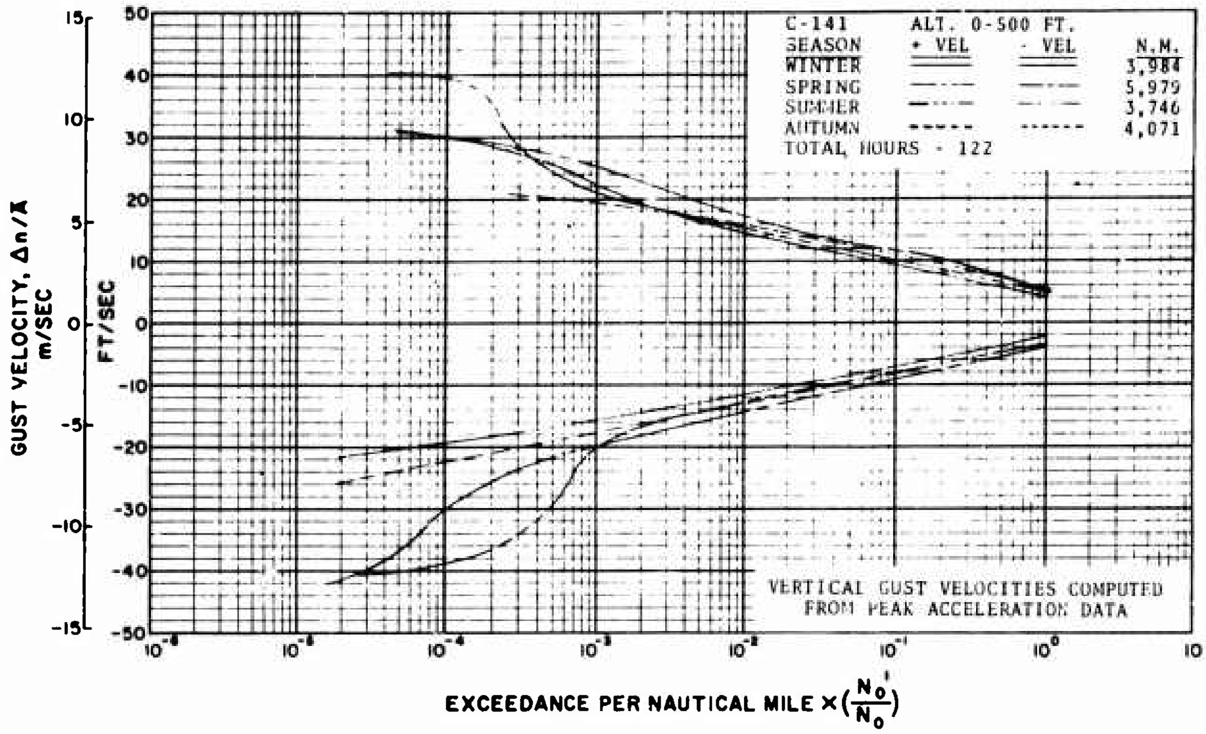

C-130 - WORLD-WIDE
ALT. 8000-10,000 FT.
SEASON + VEL - VEL N.M.
WINTER 15,691
SPRING 21,212
SUMMER 32,721
AUTUMN 17,996
TOTAL HOURS - 373
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_o'}{N_o}$)

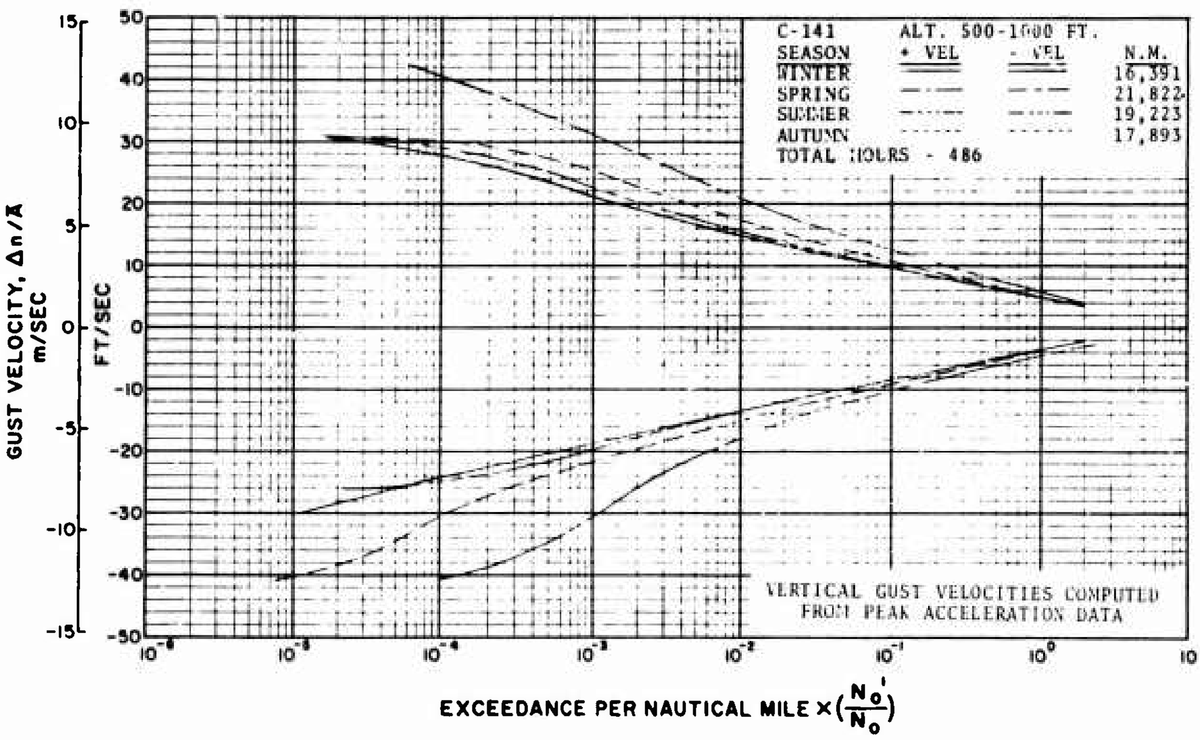

C-130 - WORLD-WIDE
ALT. 10,000-15,000 FT.
SEASON + VEL - VEL N.M.
WINTER 42,315
SPRING 61,684
SUMMER 65,178
AUTUMN 48,529
TOTAL HOURS - 898
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_o'}{N_o}$)

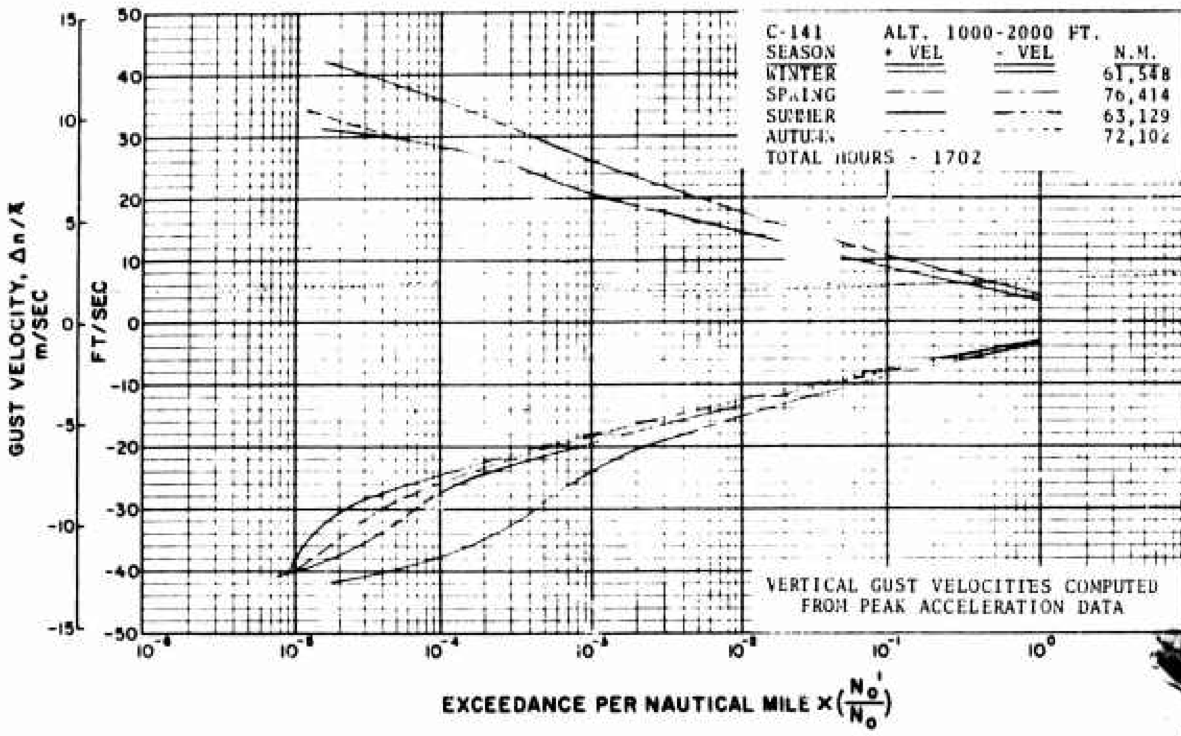

C-130 - WORLD-WIDE
ALT. 15,000-20,000 FT.
SEASON + VEL - VEL N.M.
WINTER 90,572
SPRING 191,345
SUMMER 181,566
AUTUMN 97,096
TOTAL HOURS - 2082
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_o'}{N_o}$)


C-130 - WORLD-WIDE
ALT. 20,000-25,000 FT.
SEASON + VEL - VEL N.M.
WINTER 165,366
SPRING 259,936
SUMMER 197,466
AUTUMN 91,874
TOTAL HOURS - 2506
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_o'}{N_o}$)

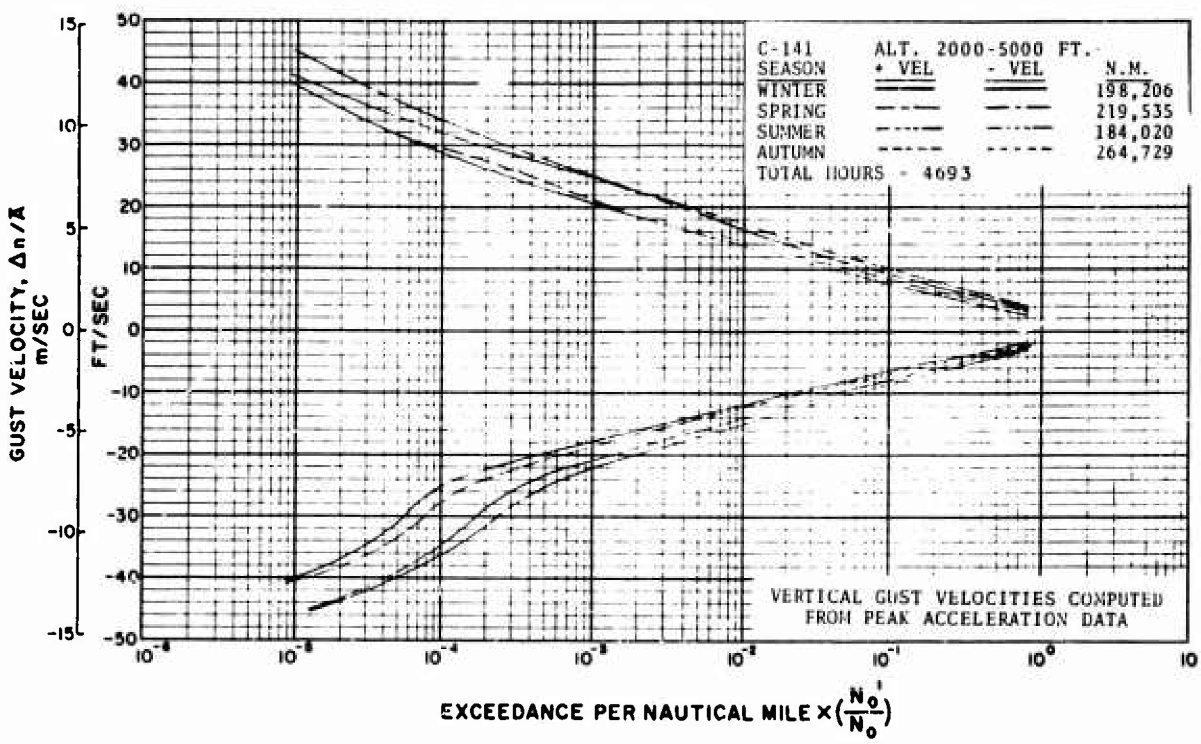

C-130 - WORLD-WIDE
ALT. 25,000-30,000 FT.
SEASON + VEL - VEL N.M.
WINTER 24,532
SPRING 50,868
SUMMER 52,655
AUTUMN 36,240
TOTAL HOURS - 582
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_o'}{N_o}$)


C-141 ALT. 0-500 FT.
SEASON + VEL - VEL N.M.
WINTER 3,984
SPRING 5,979
SUMMER 3,746
AUTUMN 4,071
TOTAL HOURS - 122
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

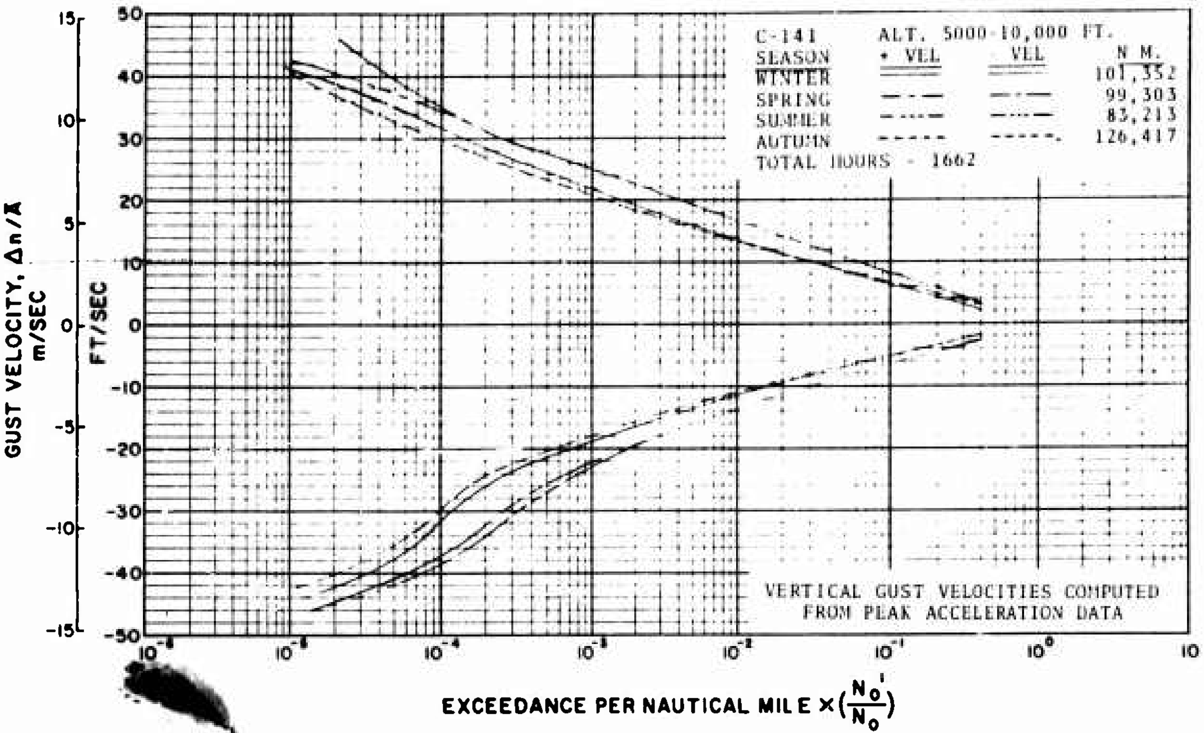

C-141 ALT. 500-1000 FT.
SEASON + VEL - VEL N.M.
WINTER 16,391
SPRING 21,822
SUMMER 19,223
AUTUMN 17,893
TOTAL HOURS - 486
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

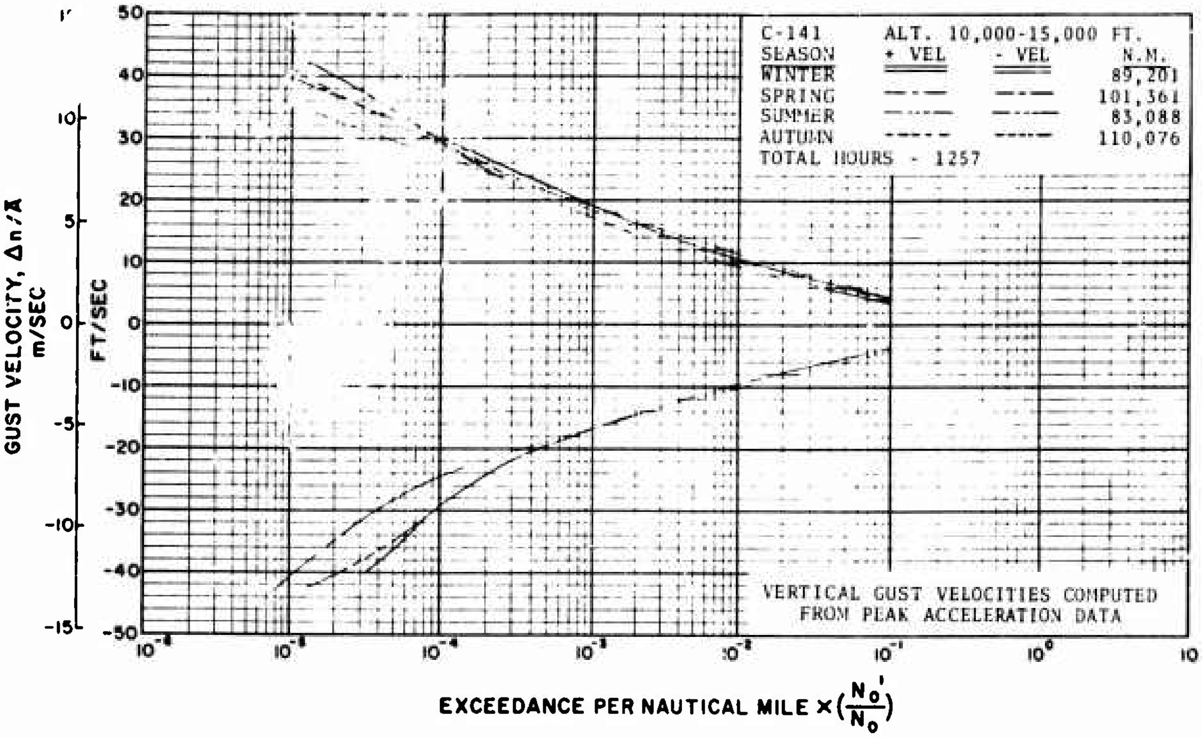


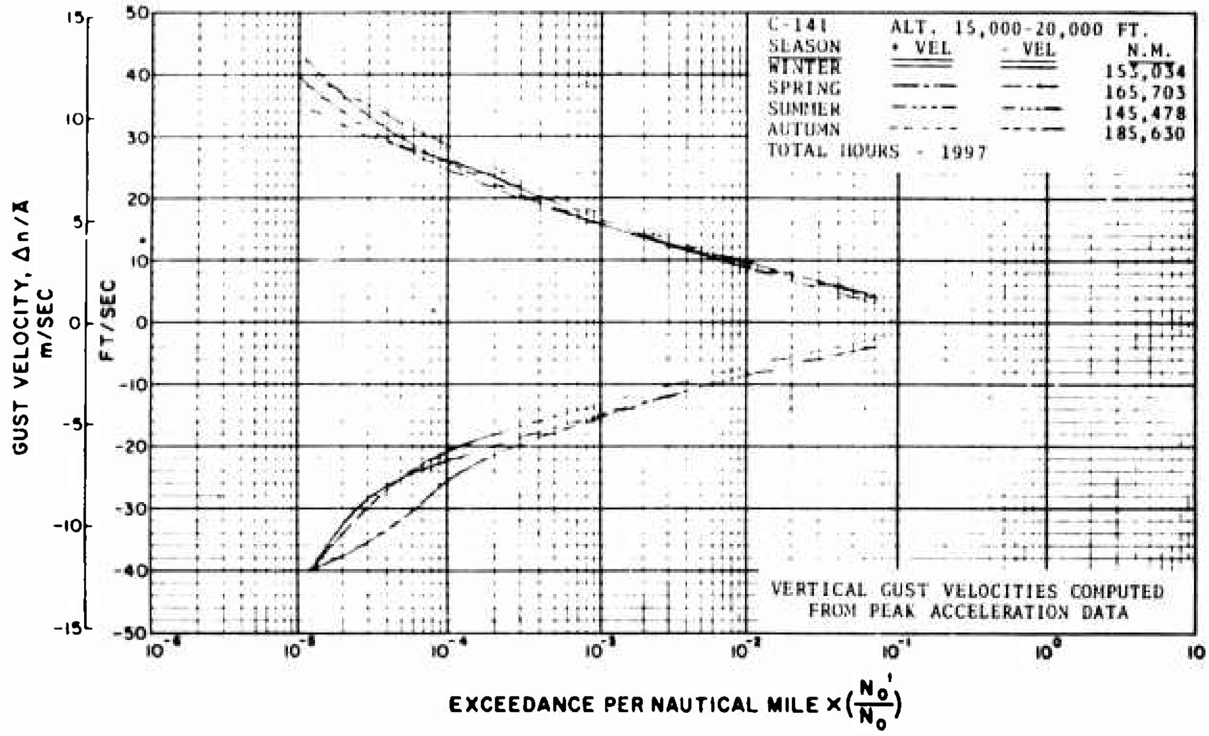
C-141 ALT. 1000-2000 FT.
SEASON + VEL - VEL N.M.
WINTER 61,548
SPRING 76,414
SUMMER 63,129
AUTUMN 72,102
TOTAL HOURS - 1702
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

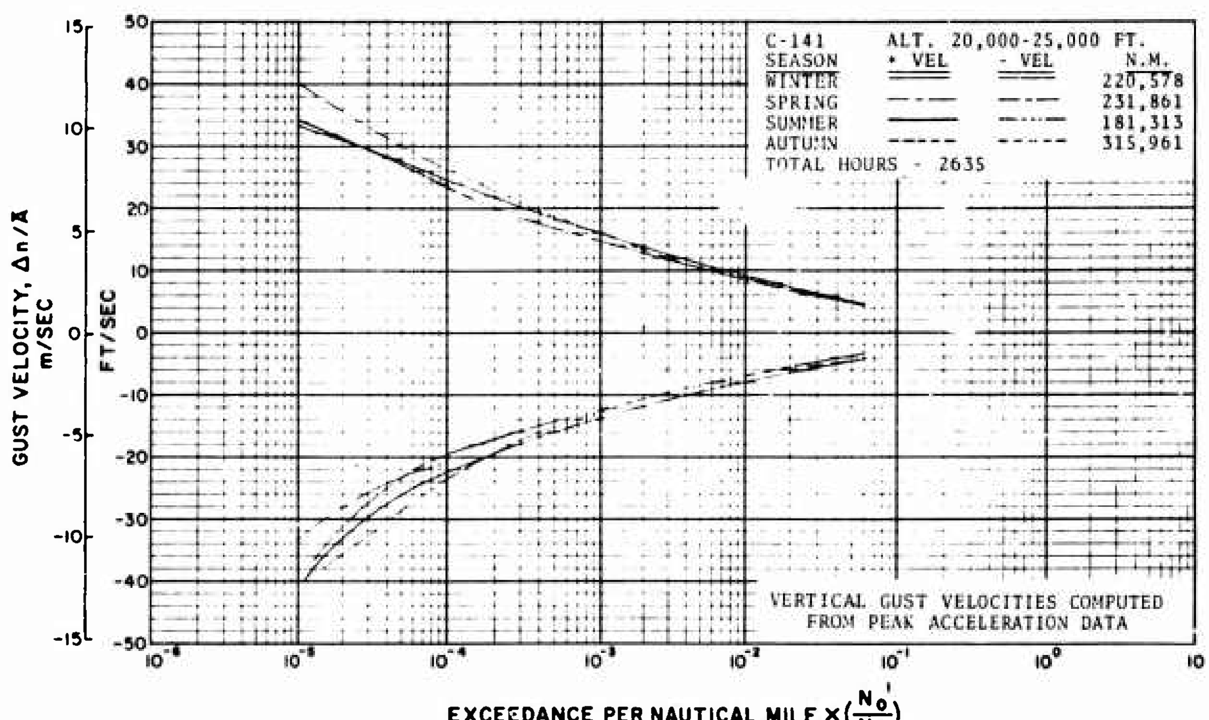


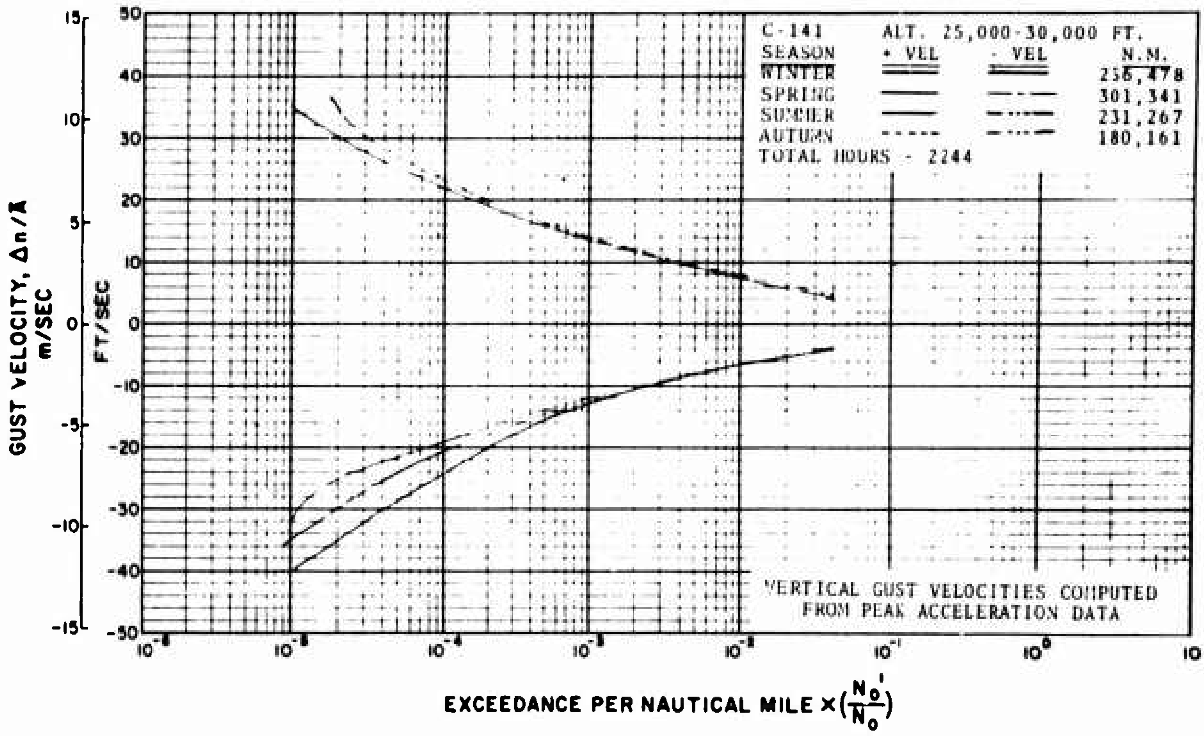
C-141 ALT. 2000-5000 FT.
SEASON + VEL - VEL N.M.
WINTER 198,206
SPRING 219,535
SUMMER 184,020
AUTUMN 264,729
TOTAL HOURS - 4693
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

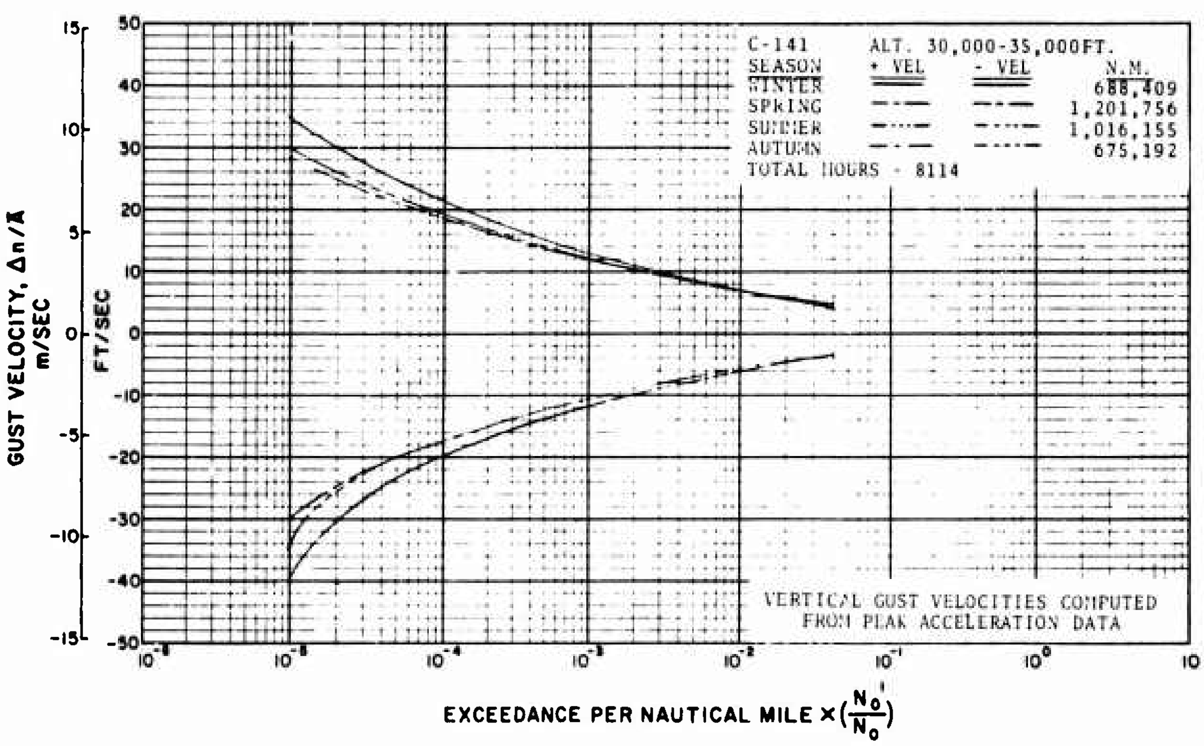

C-141 ALT. 5000-10,000 FT.
SEASON + VEL - VEL N.M.
WINTER 101,352
SPRING 99,303
SUMMER 83,213
AUTUMN 126,417
TOTAL HOURS - 1662
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

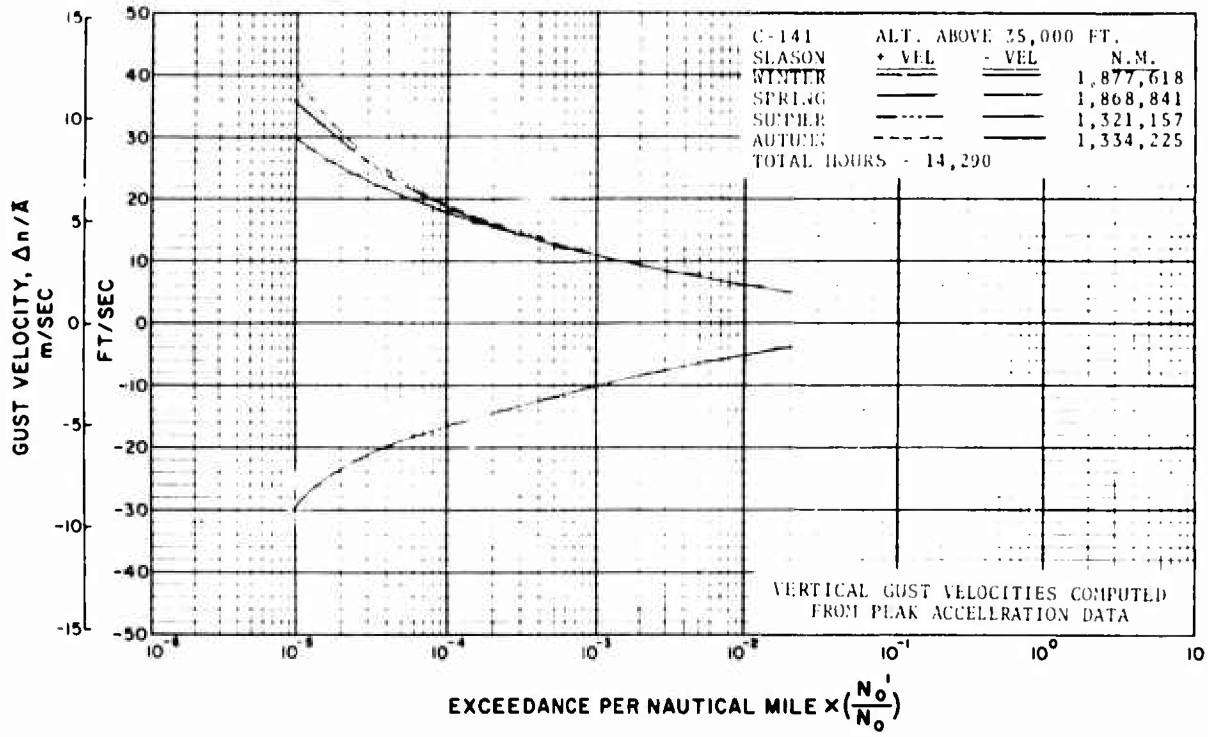

C-141 ALT. 10,000-15,000 FT.
SEASON + VEL - VEL N.M.
WINTER 89,201
SPRING 101,361
SUMMER 83,088
AUTUMN 110,076
TOTAL HOURS - 1257
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

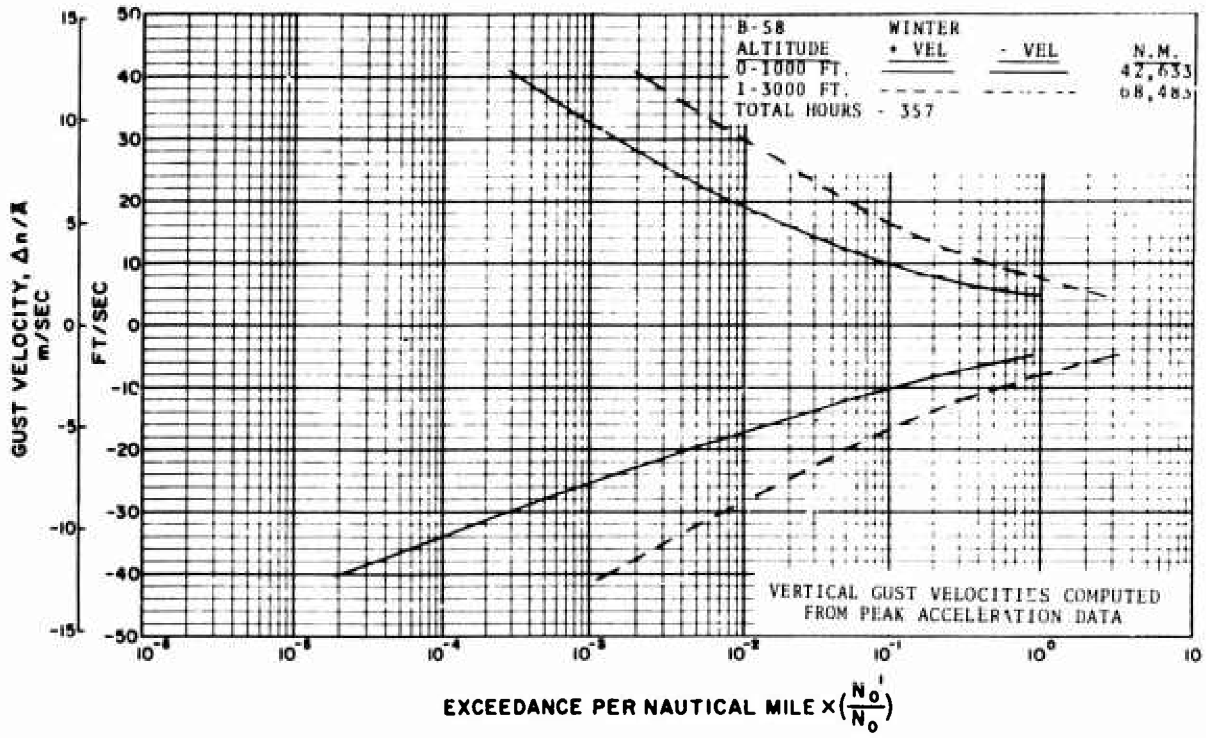

C-141 ALT. 15,000-20,000 FT.
SEASON + VEL - VEL N.M.
WINTER 153,034
SPRING 165,703
SUMMER 145,478
AUTUMN 185,630
TOTAL HOURS - 1997
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

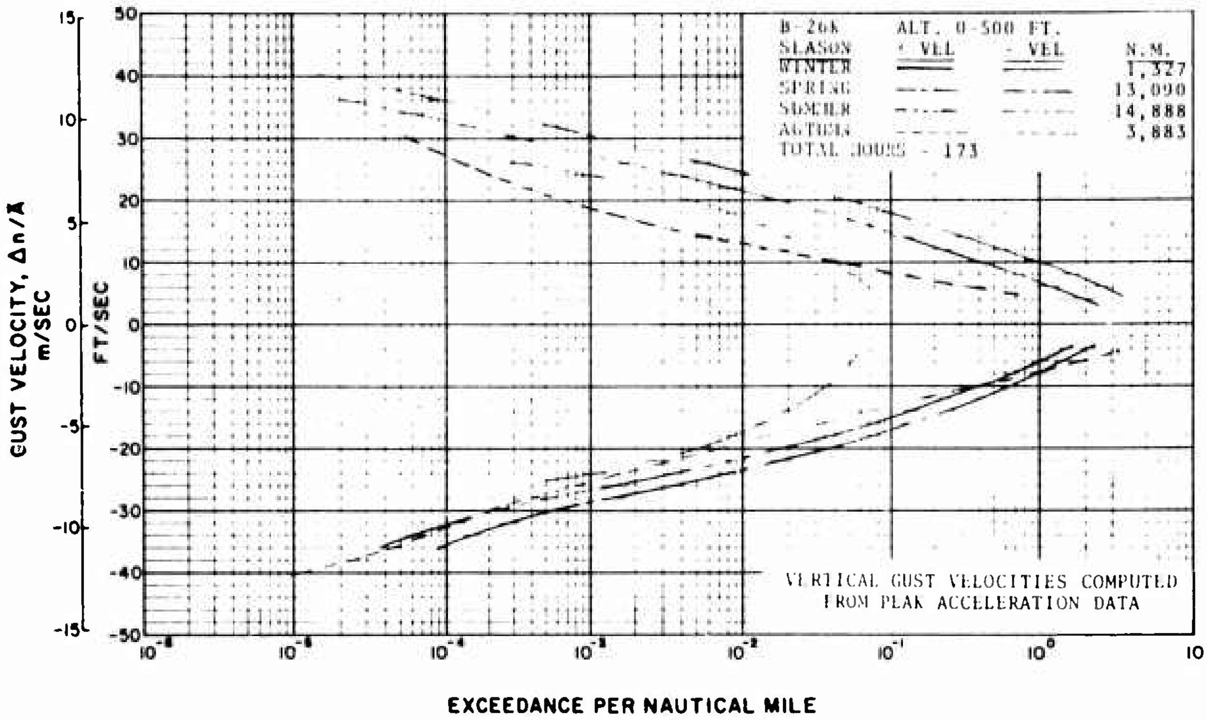

C-141 ALT. 20,000-25,000 FT.
SEASON + VEL - VEL N.M.
WINTER 220,578
SPRING 231,861
SUMMER 181,313
AUTUMN 315,961
TOTAL HOURS - 2635
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

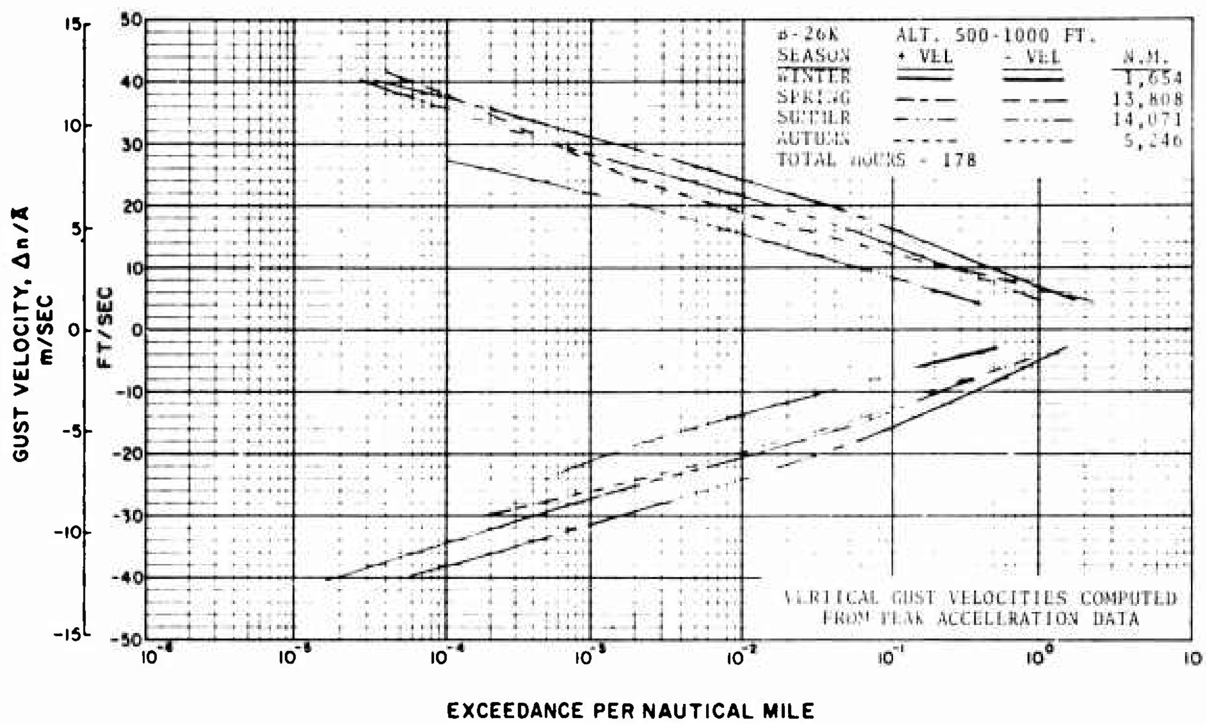

C-141 ALT. 25,000-30,000 FT.
SEASON + VEL - VEL N.M.
WINTER 236,478
SPRING 301,341
SUMMER 231,267
AUTUMN 180,161
TOTAL HOURS - 2244
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, $\Delta n/\bar{A}$ m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE $\times \left(\frac{N_0'}{N_0}\right)$

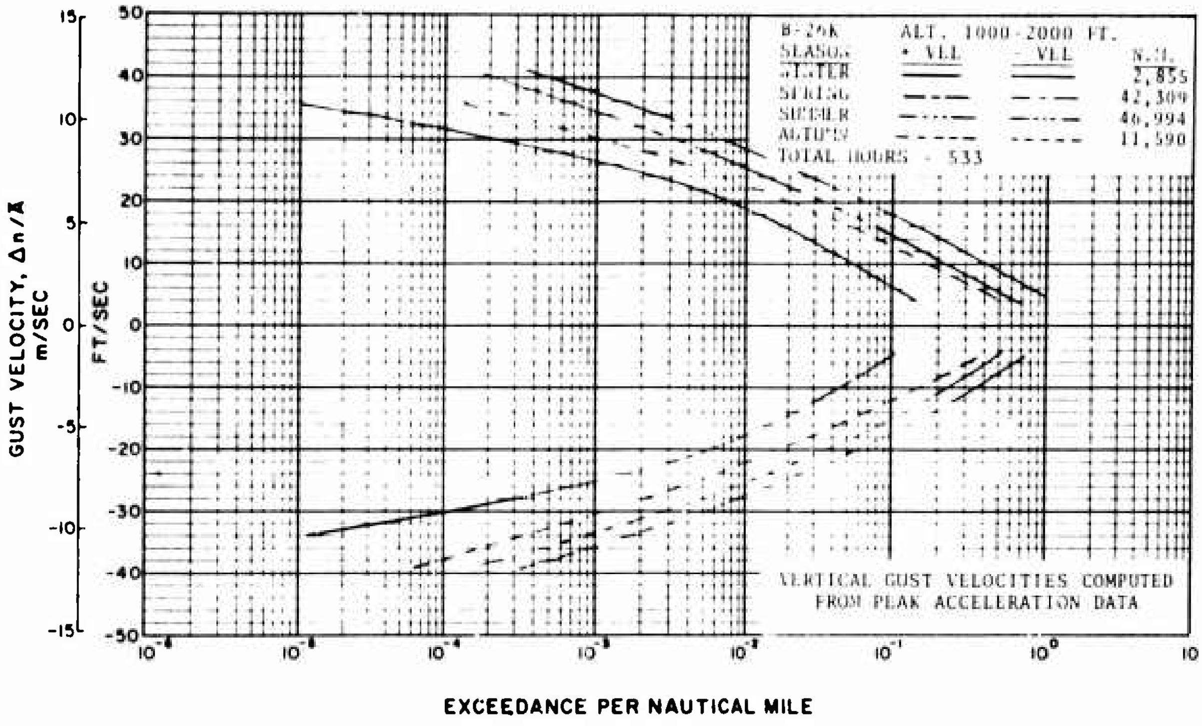

C-141 ALT. 30,000-35,000FT.
SEASON + VEL - VEL N.M.
WINTER 688,409
SPRING 1,201,756
SUMMER 1,016,155
AUTUMN 675,192
TOTAL HOURS - 8114
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, $\Delta n/\bar{A}$ m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE $\times \left(\frac{N_0'}{N_0}\right)$

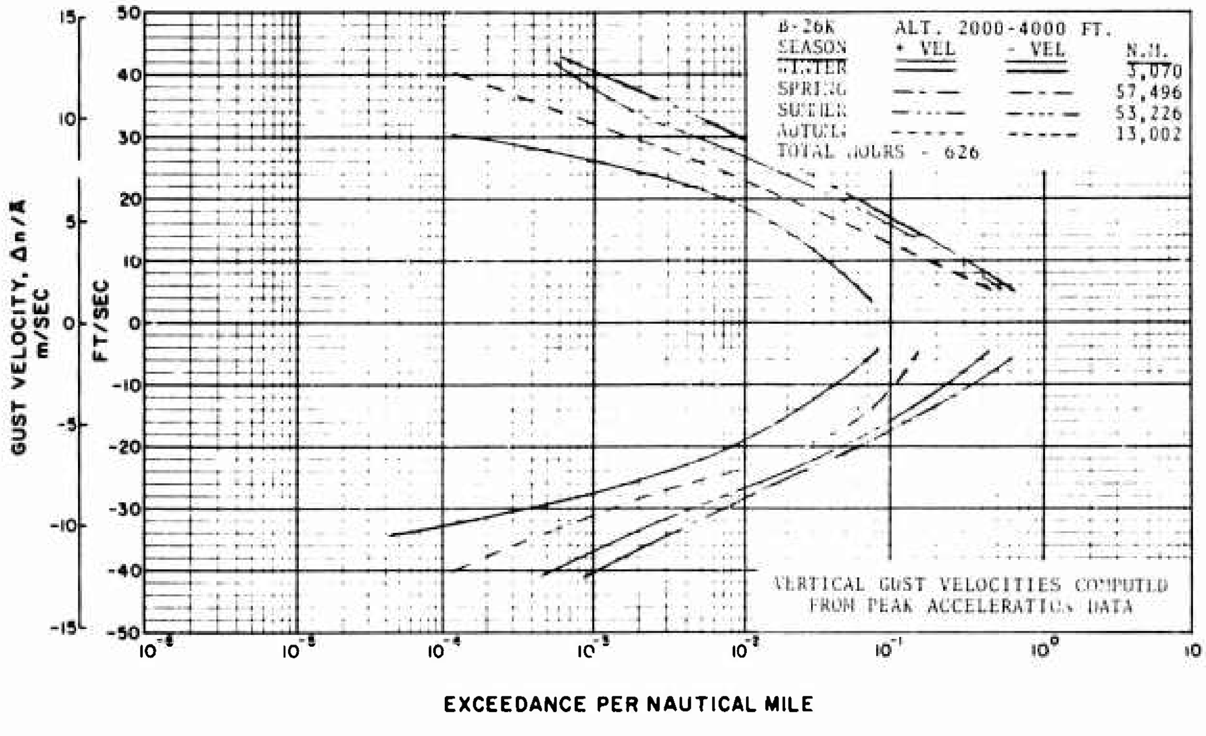

C-141 ALT. ABOVE 35,000 FT.
SEASON + VEL - VEL N.M.
WINTER 1,877,618
SPRING 1,868,841
SUMMER 1,321,157
AUTUMN 1,334,225
TOTAL HOURS - 14,290
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

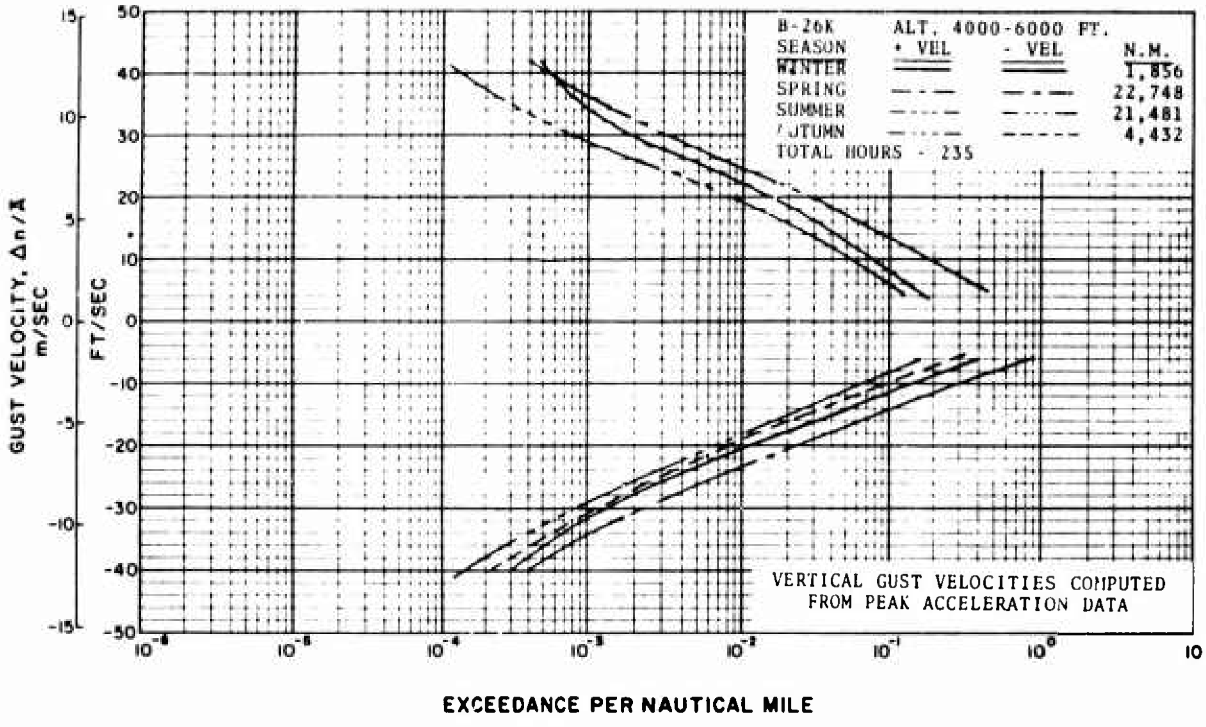

B-58
WINTER
ALTITUDE
+ VEL
- VEL
N.M.
0-1000 FT.
42,633
1-3000 FT.
68,483
TOTAL HOURS - 357
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE ×($\frac{N_0'}{N_0}$)

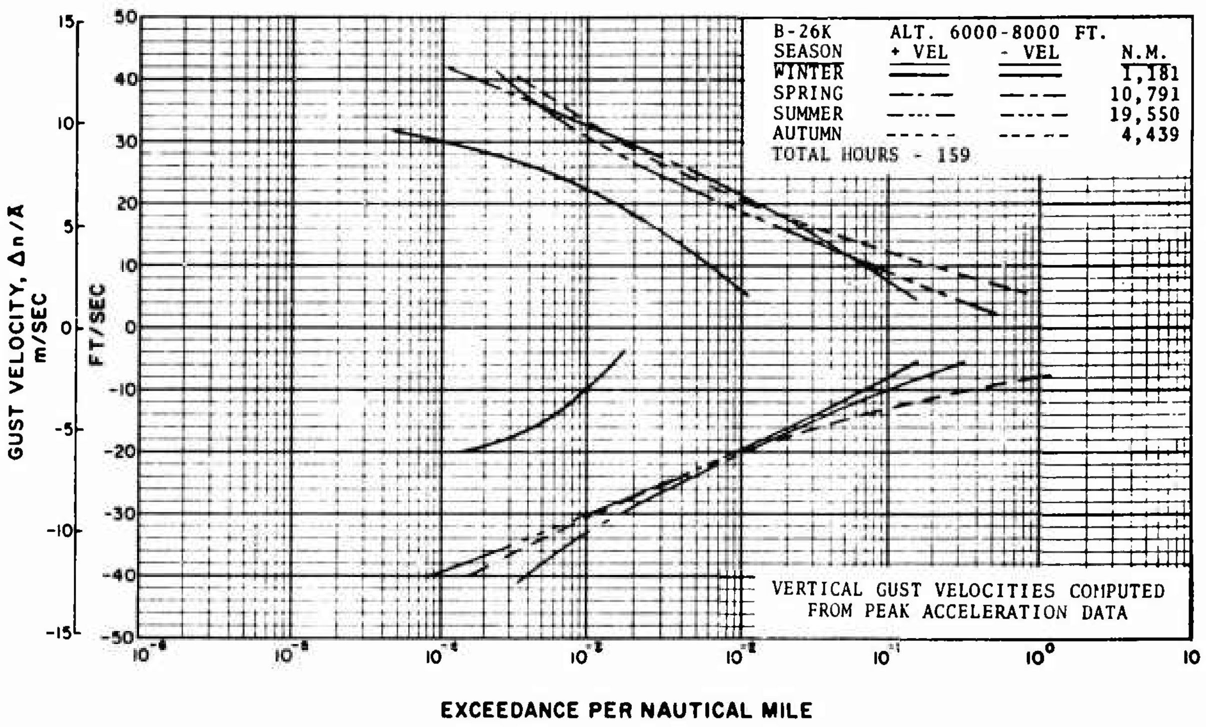

B-26K ALT. 0-500 FT.
SEASON + VEL - VEL N.M.
WINTER 1,327
SPRING 13,090
SUMMER 14,888
AUTUMN 3,883
TOTAL HOURS - 173
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

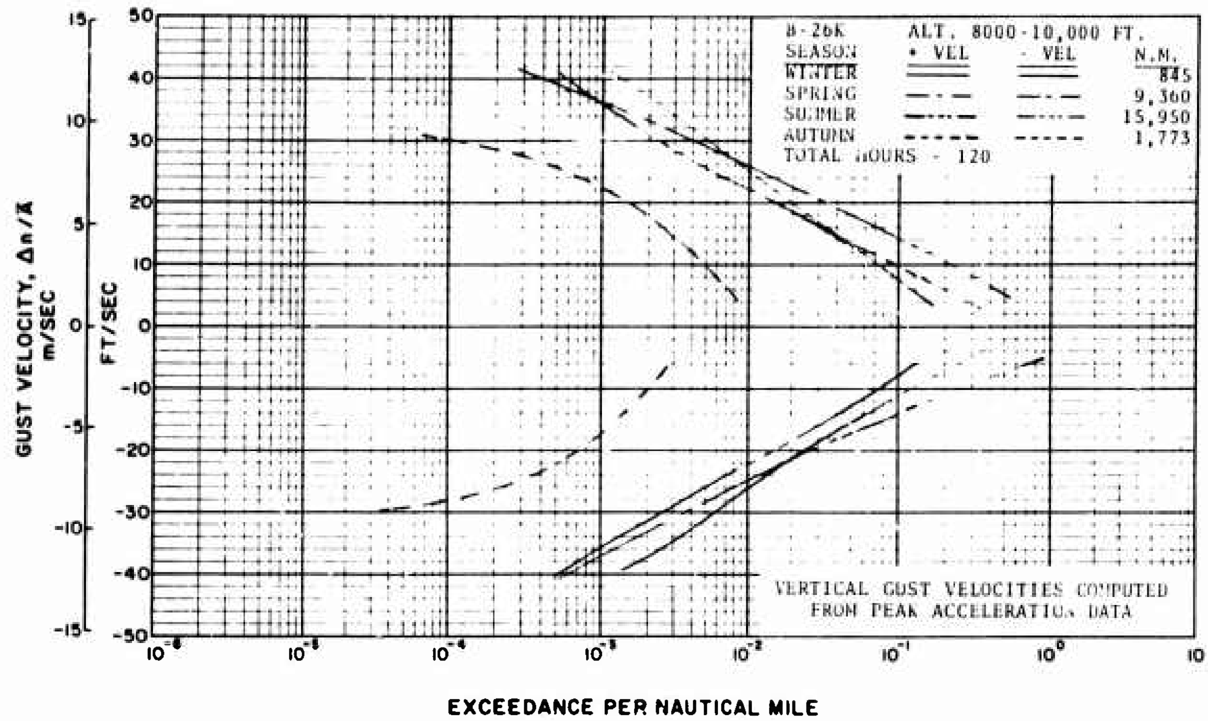

B-26K ALT. 500-1000 FT.
SEASON + VEL - VEL N.M.
WINTER 1,654
SPRING 13,808
SUMMER 14,071
AUTUMN 5,246
TOTAL HOURS - 178
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

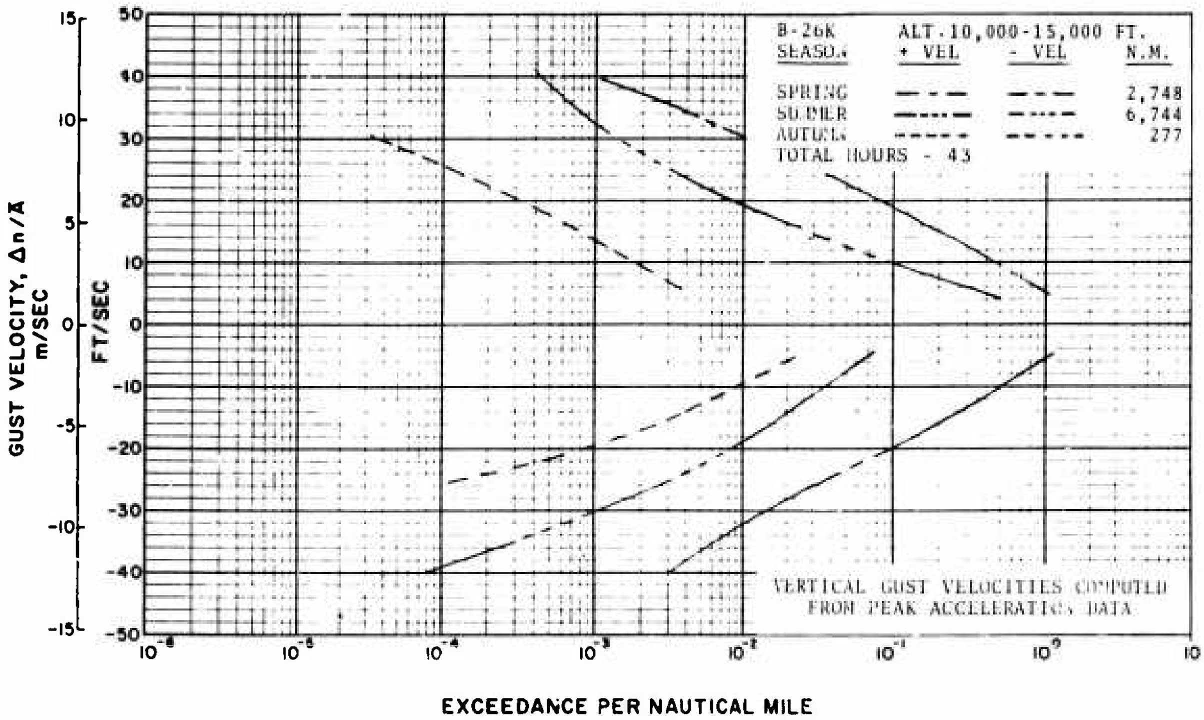

B-26K
ALT. 1000-2000 FT.
SEASON
+ VEL
- VEL
N.M.
WINTER
2,855
SPRING
42,309
SUMMER
46,994
AUTUMN
11,590
TOTAL HOURS - 533
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

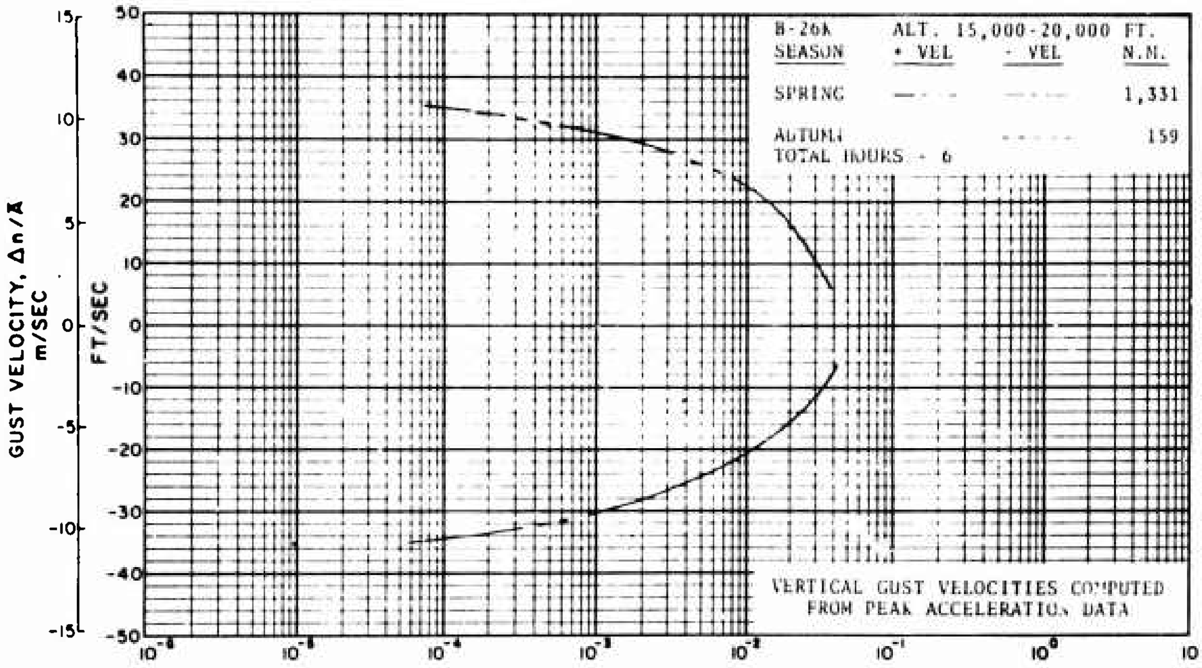

B-26K
ALT. 2000-4000 FT.
SEASON
+ VEL
- VEL
N.M.
WINTER
3,070
SPRING
57,496
SUMMER
53,226
AUTUMN
13,002
TOTAL HOURS - 626
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


B-26K ALT. 4000-6000 FT.
SEASON + VEL - VEL N.M.
WINTER 1,856
SPRING 22,748
SUMMER 21,481
AUTUMN 4,432
TOTAL HOURS - 235
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

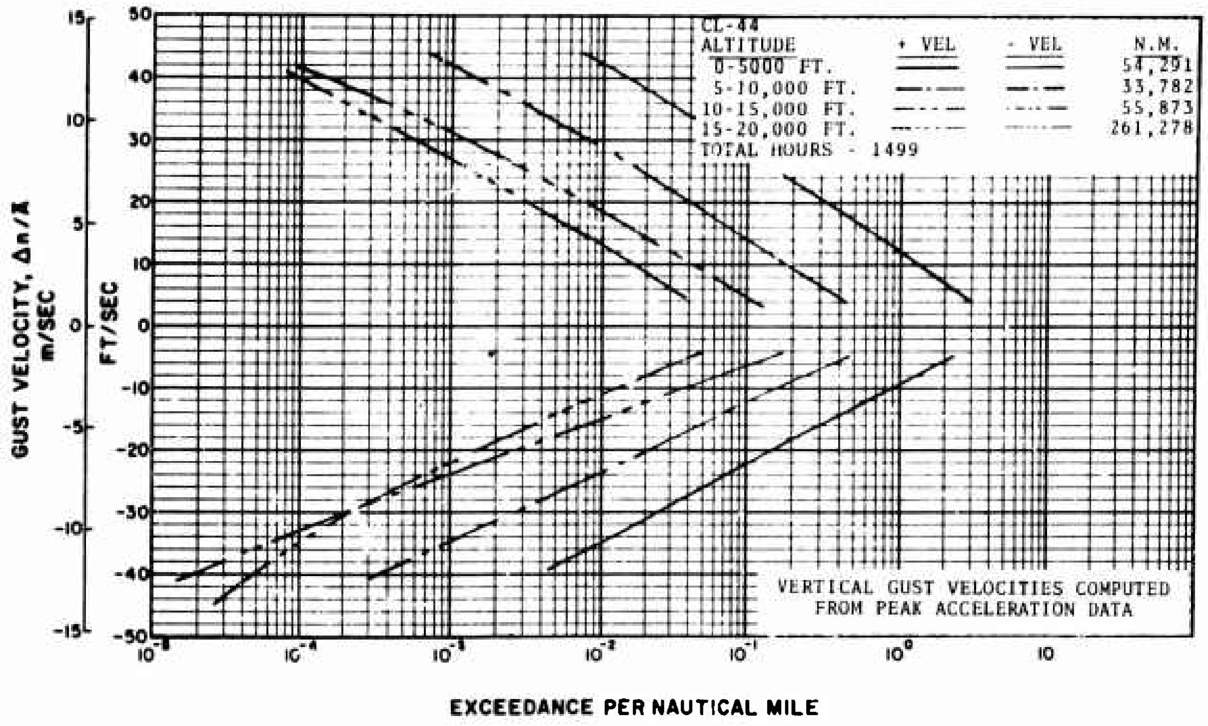

B-26K ALT. 6000-8000 FT.
SEASON + VEL - VEL N.M.
WINTER 1,181
SPRING 10,791
SUMMER 19,550
AUTUMN 4,439
TOTAL HOURS - 159
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


B-26K ALT. 8000-10,000 FT.
SEASON + VEL - VEL N.M.
WINTER 845
SPRING 9,360
SUMMER 15,950
AUTUMN 1,773
TOTAL HOURS - 120
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

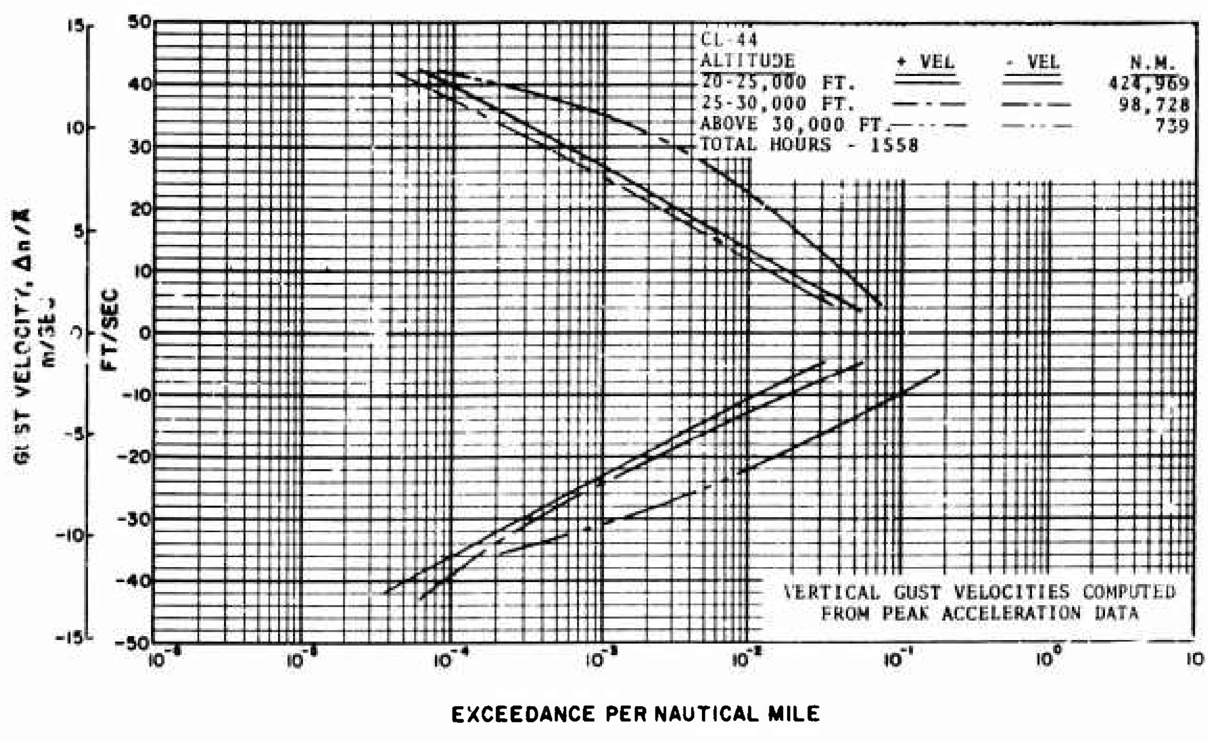

B-26K ALT-10,000-15,000 FT.
SEASON + VEL - VEL N.M.
SPRING 2,748
SUMMER 6,744
AUTUMN 277
TOTAL HOURS - 43
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE



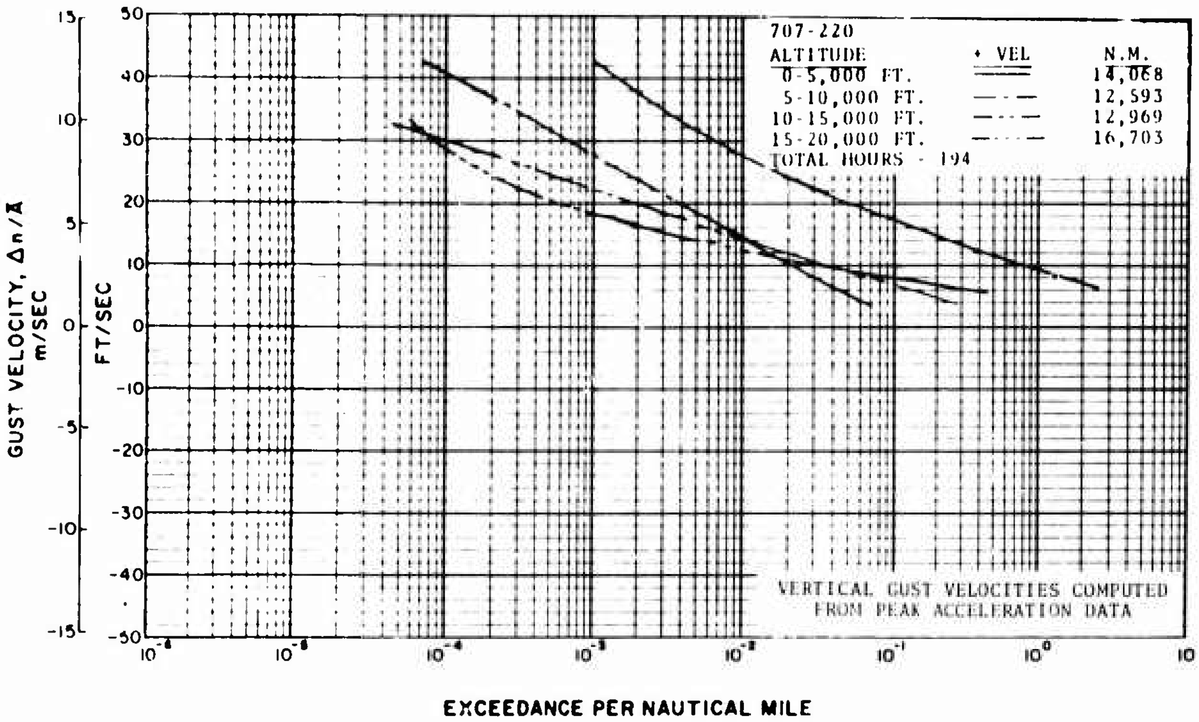
EXCEEDANCE PER NAUTICAL MILE

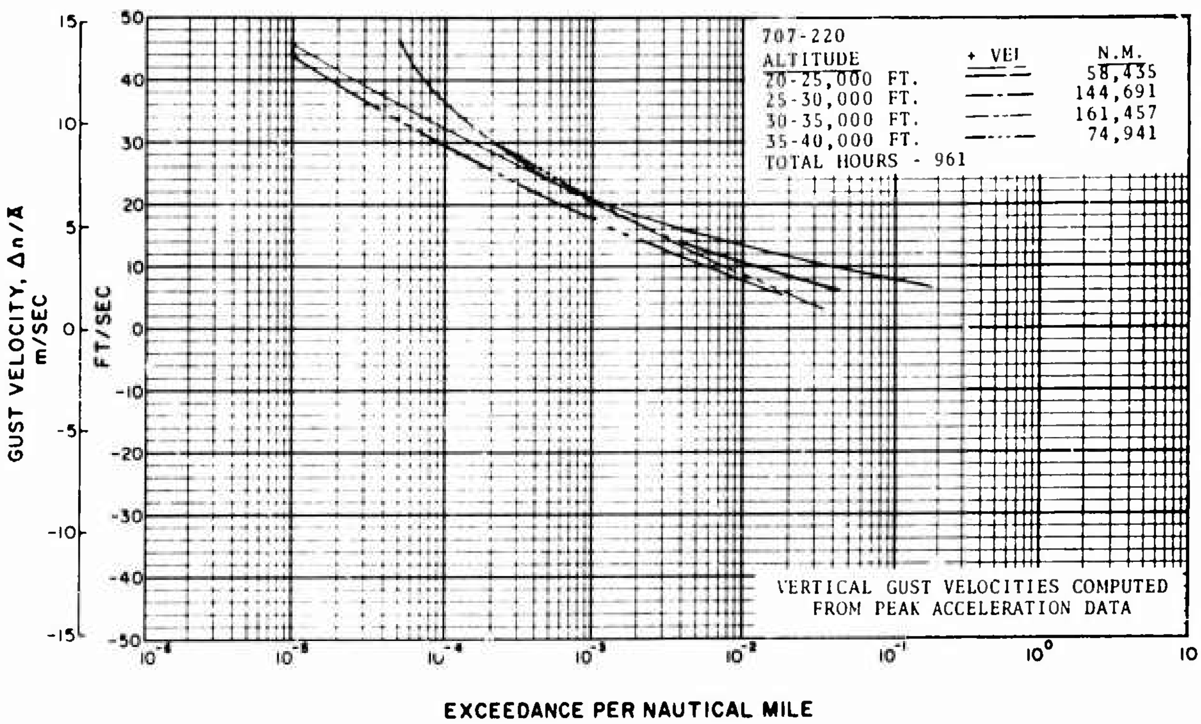


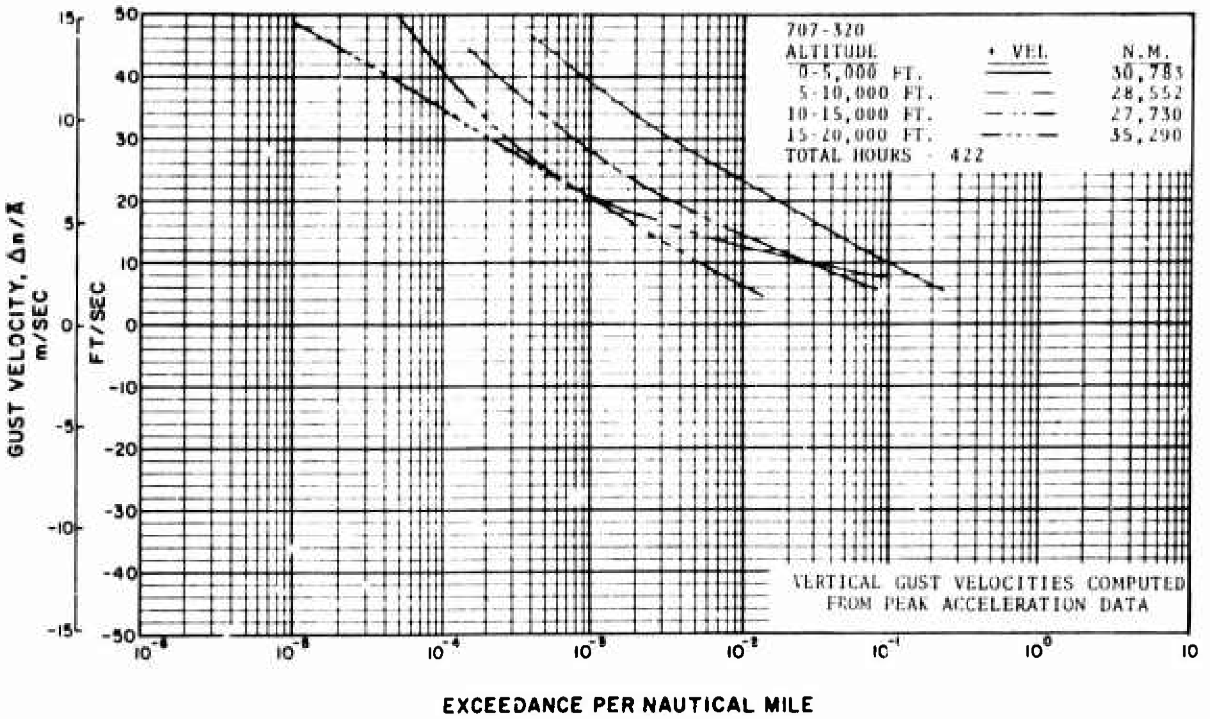
CL-44
ALTITUDE
+ VEL
- VEL
N.M.
0-5000 FT.
54,291
5-10,000 FT.
33,782
10-15,000 FT.
55,873
15-20,000 FT.
261,278
TOTAL HOURS - 1499
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE



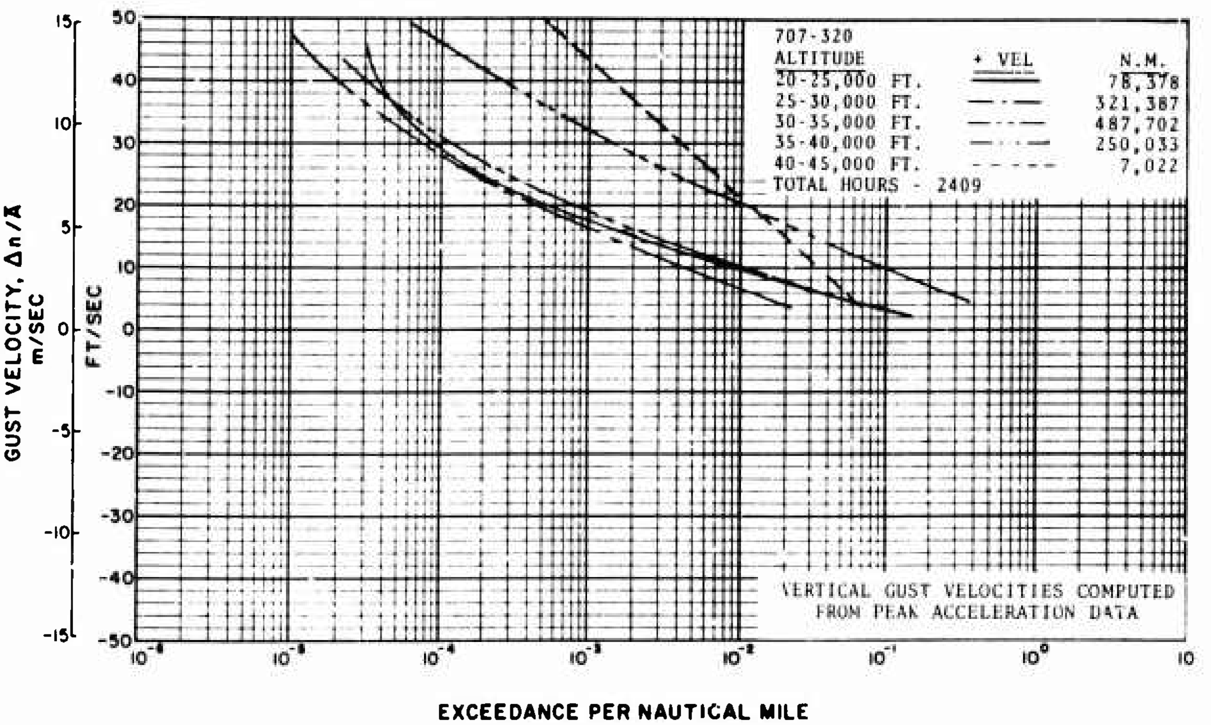
CL-44
ALTITUDE
+ VEL
- VEL
N.M.
20-25,000 FT.
424,969
25-30,000 FT.
98,728
ABOVE 30,000 FT.
739
TOTAL HOURS - 1558
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


707-220
ALTITUDE
+ VEL
N.M.
0-5,000 FT. 14,068
5-10,000 FT. 12,593
10-15,000 FT. 12,969
15-20,000 FT. 16,703
TOTAL HOURS - 194
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

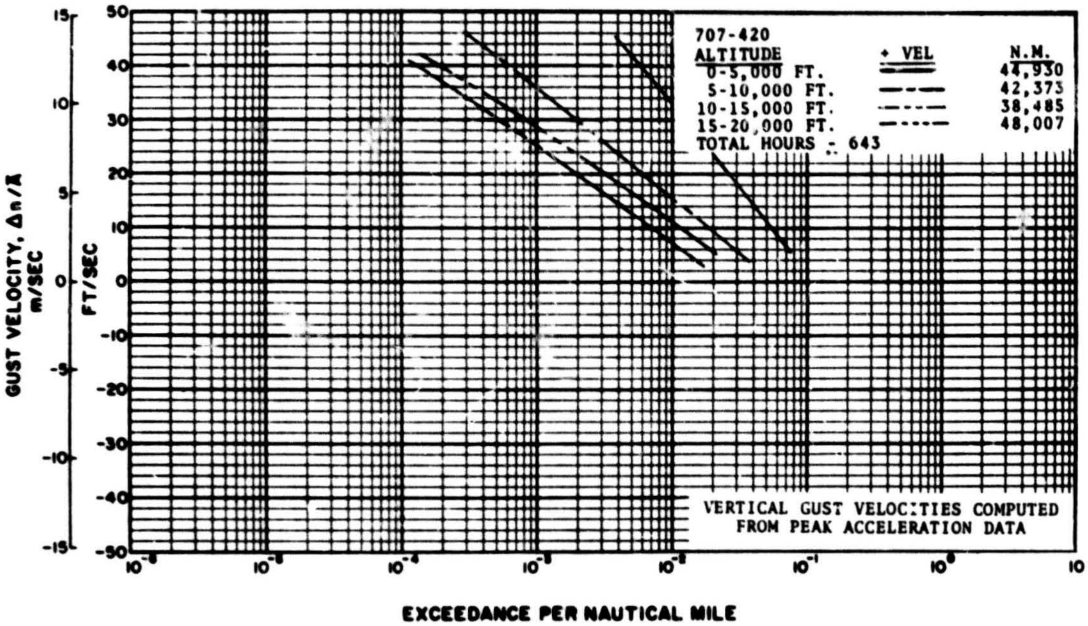

707-220
ALTITUDE
+ VEL
N.M.
20-25,000 FT. 58,435
25-30,000 FT. 144,691
30-35,000 FT. 161,457
35-40,000 FT. 74,941
TOTAL HOURS - 961
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

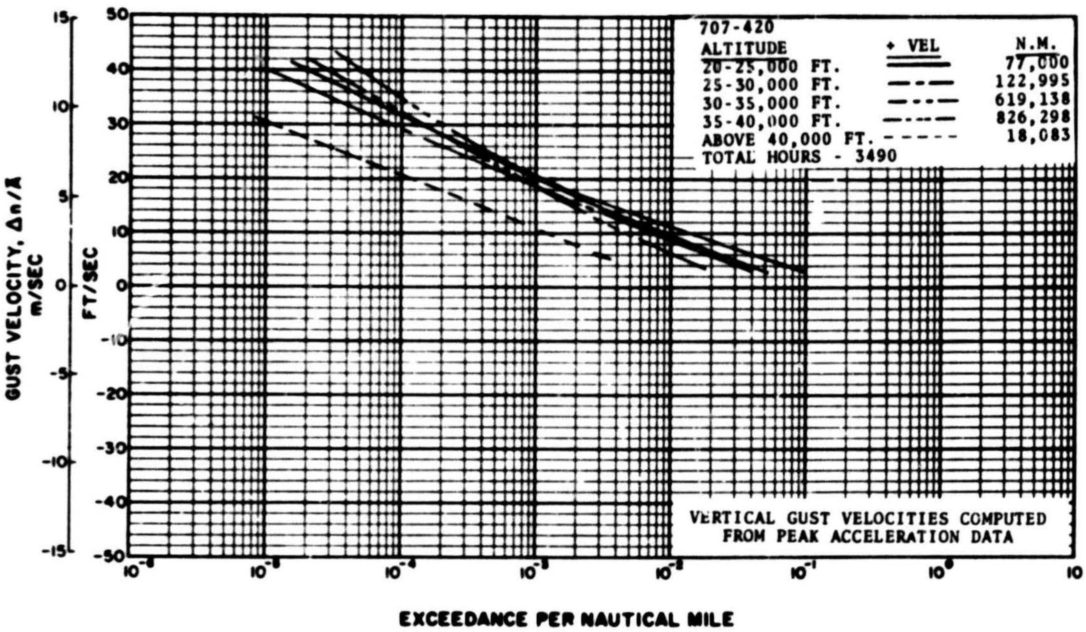


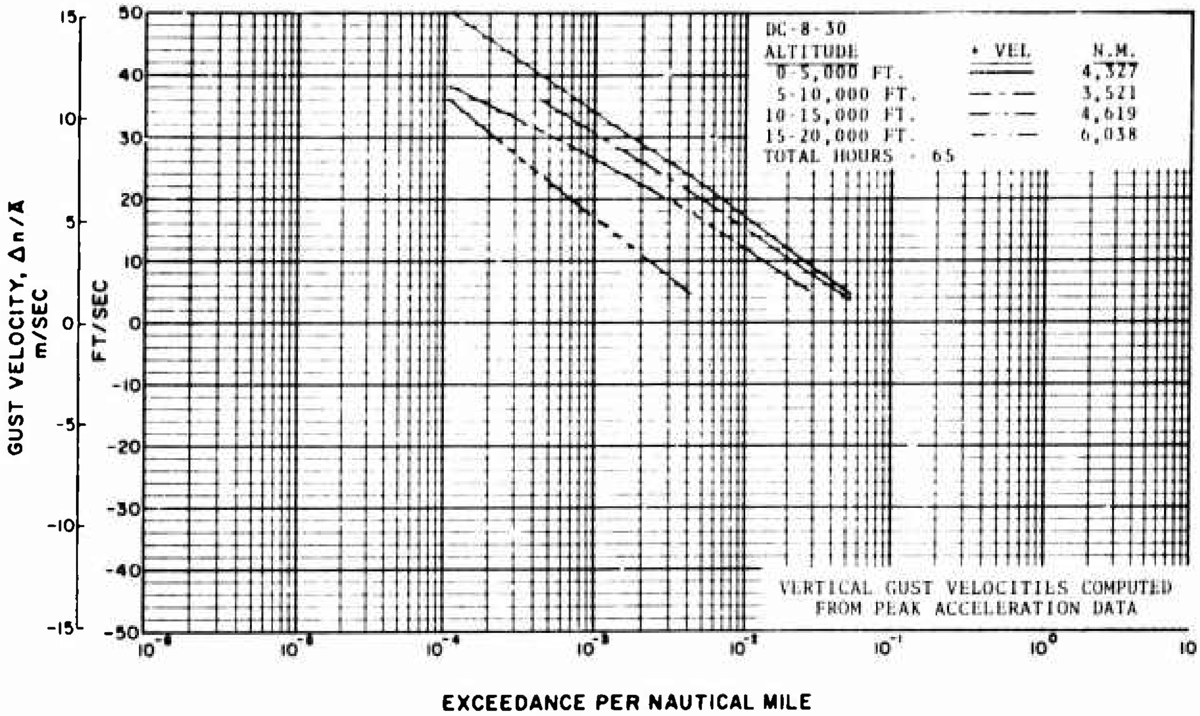
707-320
ALTITUDE
+ VEL
N.M.
0-5,000 FT.
30,783
5-10,000 FT.
28,552
10-15,000 FT.
27,730
15-20,000 FT.
35,290
TOTAL HOURS - 422
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

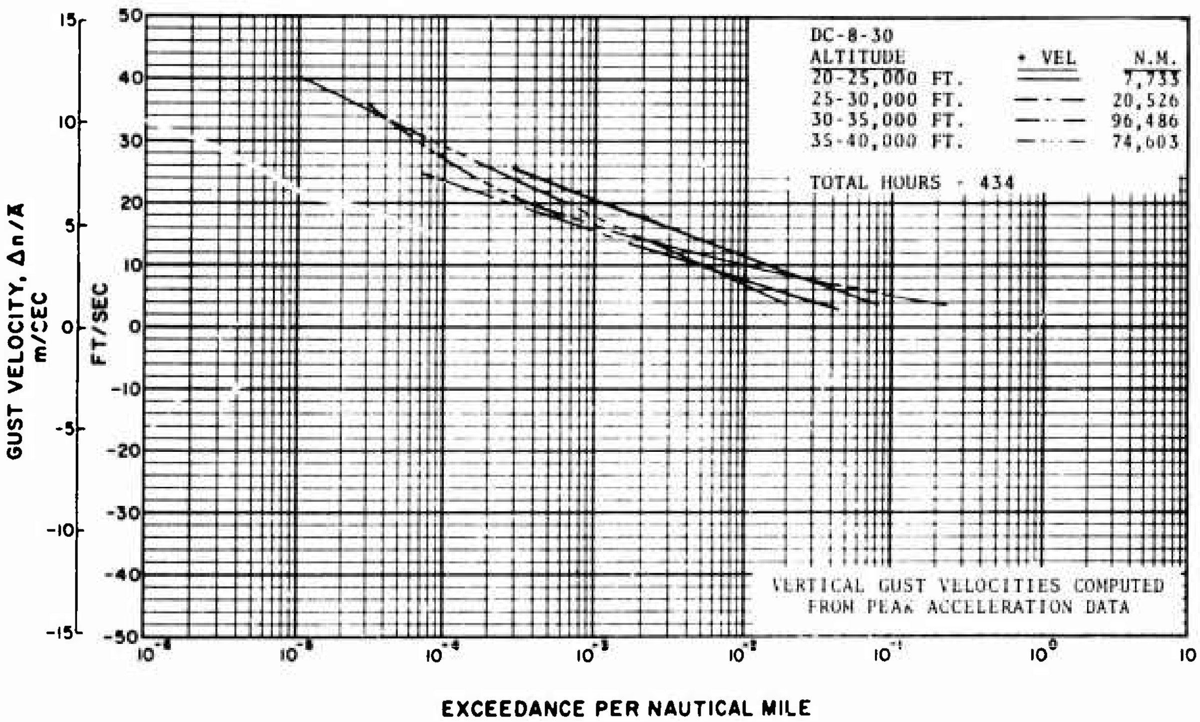


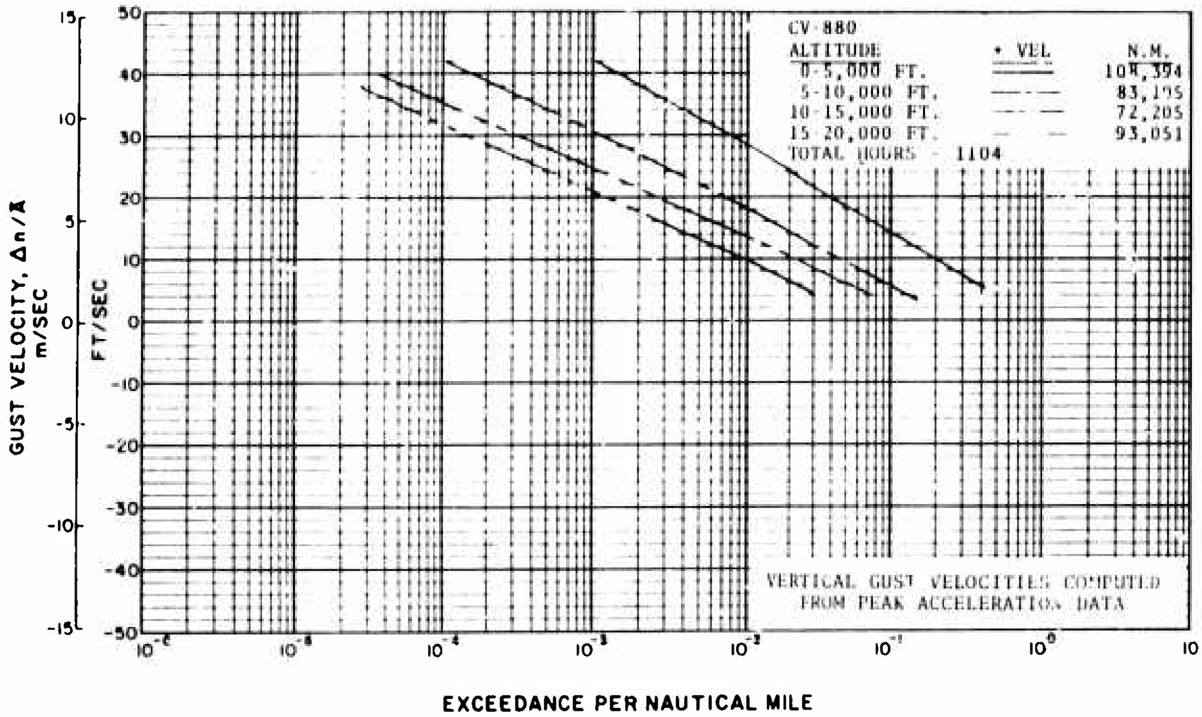
707-320
ALTITUDE
+ VEL
N.M.
20-25,000 FT.
78,378
25-30,000 FT.
321,387
30-35,000 FT.
487,702
35-40,000 FT.
250,033
40-45,000 FT.
7,022
TOTAL HOURS - 2409
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

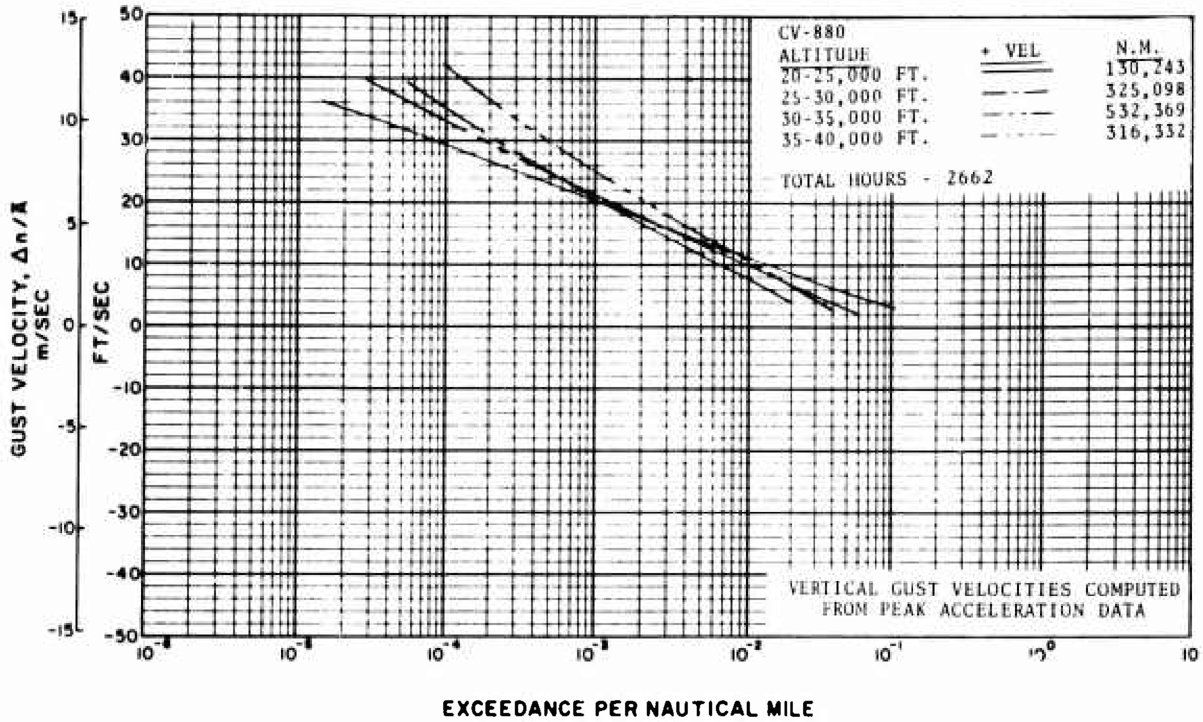

707-420
ALTITUDE
+ VEL
N.M.
0-5,000 FT. 44,930
5-10,000 FT. 42,373
10-15,000 FT. 38,485
15-20,000 FT. 48,007
TOTAL HOURS - 643
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

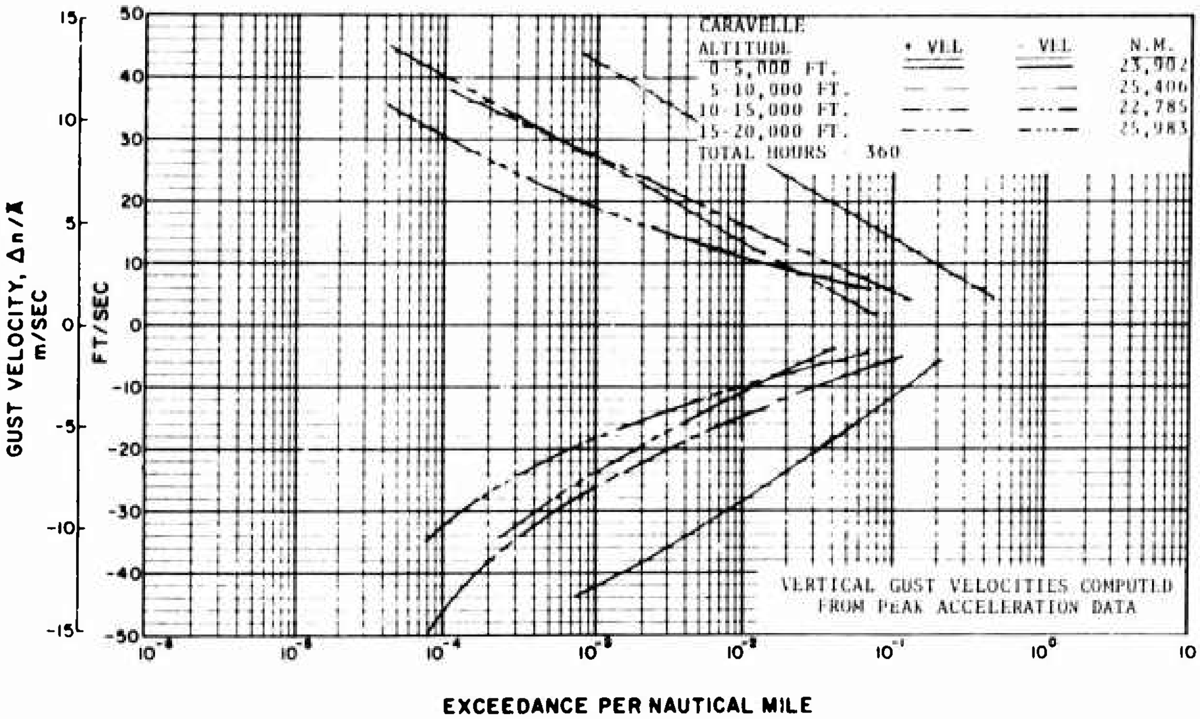

707-420
ALTITUDE
+ VEL
N.M.
20-25,000 FT. 77,000
25-30,000 FT. 122,995
30-35,000 FT. 619,138
35-40,000 FT. 826,298
ABOVE 40,000 FT. 18,083
TOTAL HOURS - 3490
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

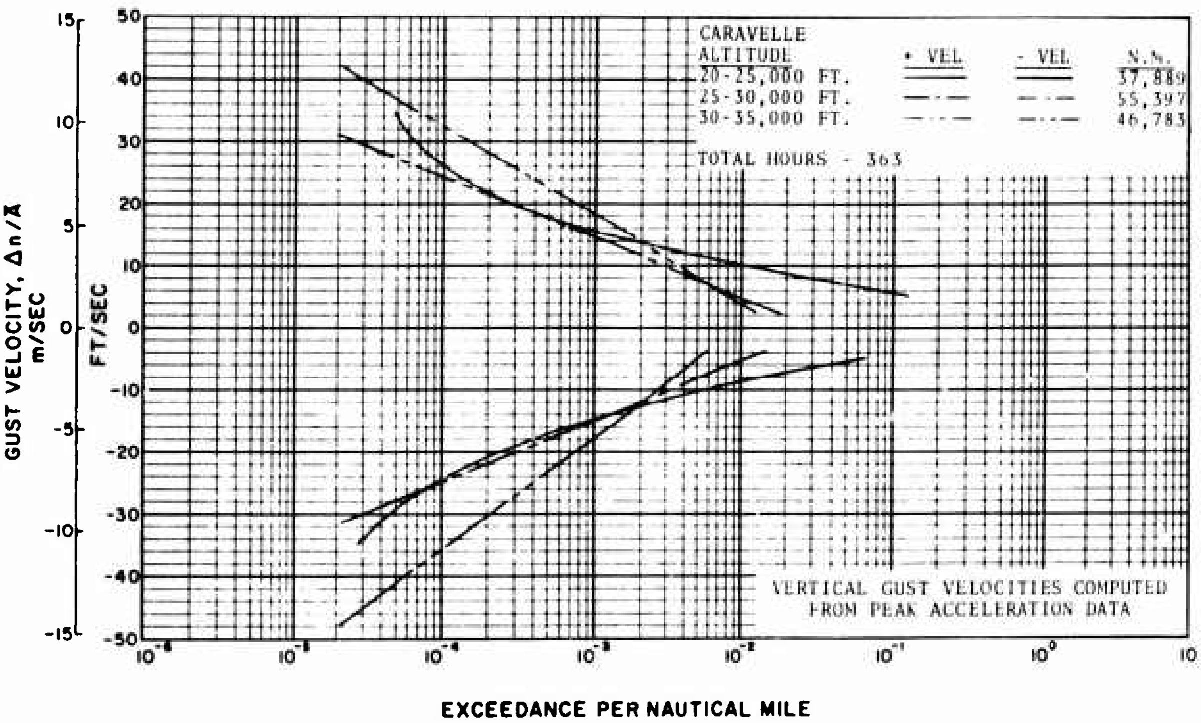

DC-8-30
ALTITUDE
+ VEL
N.M.
0-5,000 FT. 4,327
5-10,000 FT. 3,521
10-15,000 FT. 4,619
15-20,000 FT. 6,038
TOTAL HOURS - 65
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

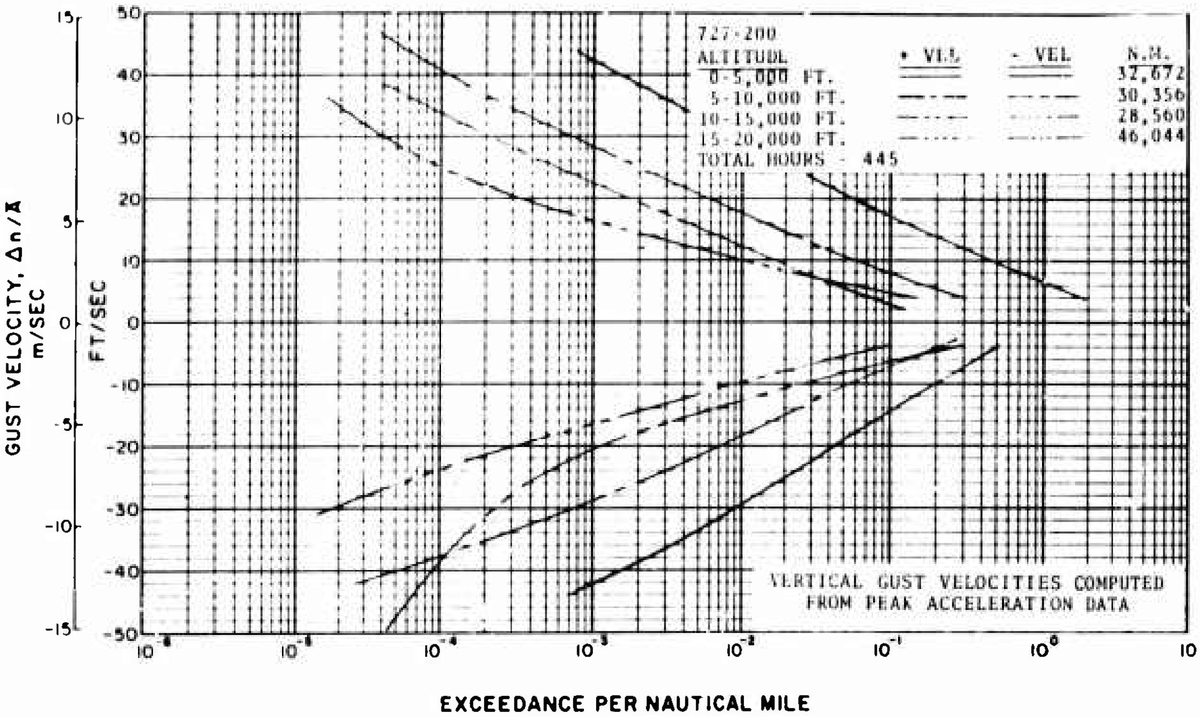

DC-8-30
ALTITUDE
+ VEL
N.M.
20-25,000 FT. 7,733
25-30,000 FT. 20,526
30-35,000 FT. 96,486
35-40,000 FT. 74,603
TOTAL HOURS - 434
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

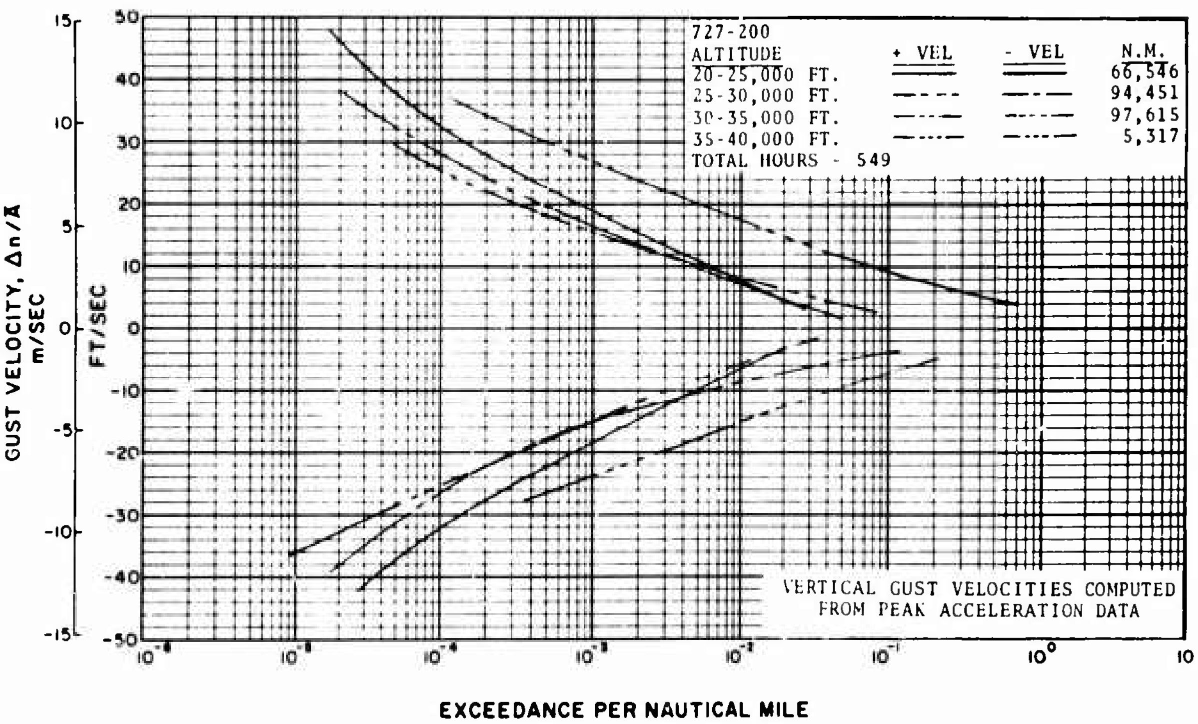

CV-880
ALTITUDE
+ VEL
N.M.
0-5,000 FT. 104,394
5-10,000 FT. 83,195
10-15,000 FT. 72,205
15-20,000 FT. 93,051
TOTAL HOURS - 1104
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

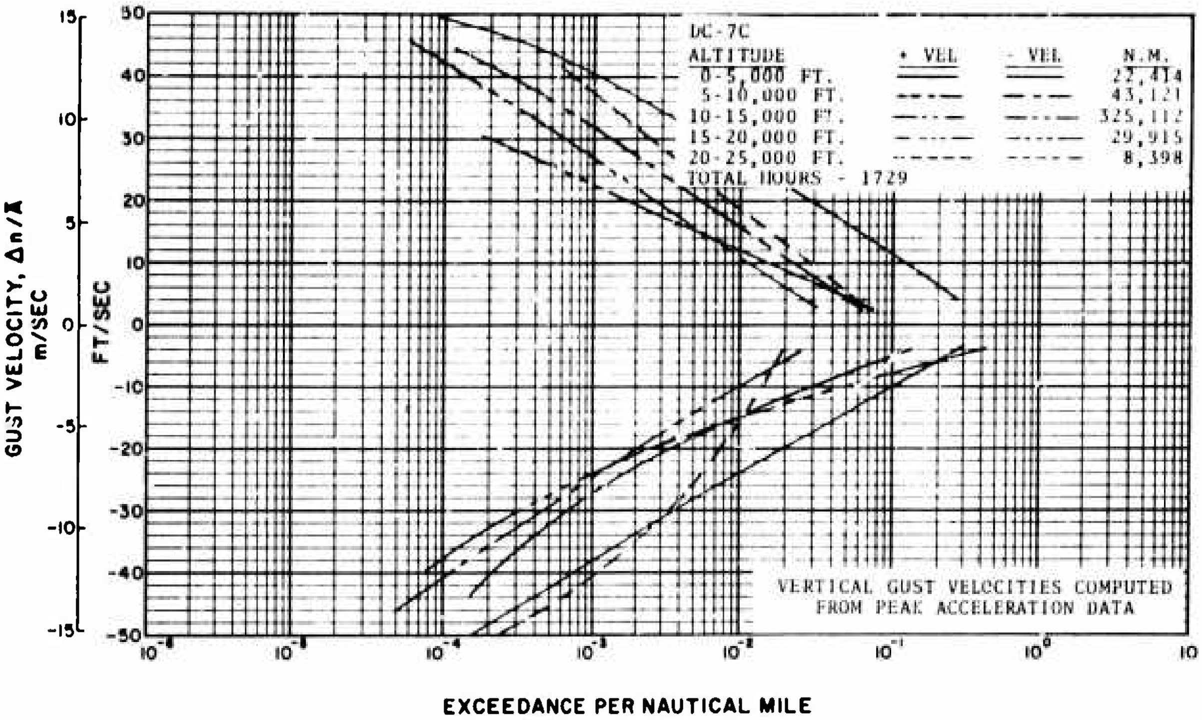

CV-880
ALTITUDE
+ VEL
N.M.
20-25,000 FT. 130,243
25-30,000 FT. 325,098
30-35,000 FT. 532,369
35-40,000 FT. 316,332
TOTAL HOURS - 2662
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

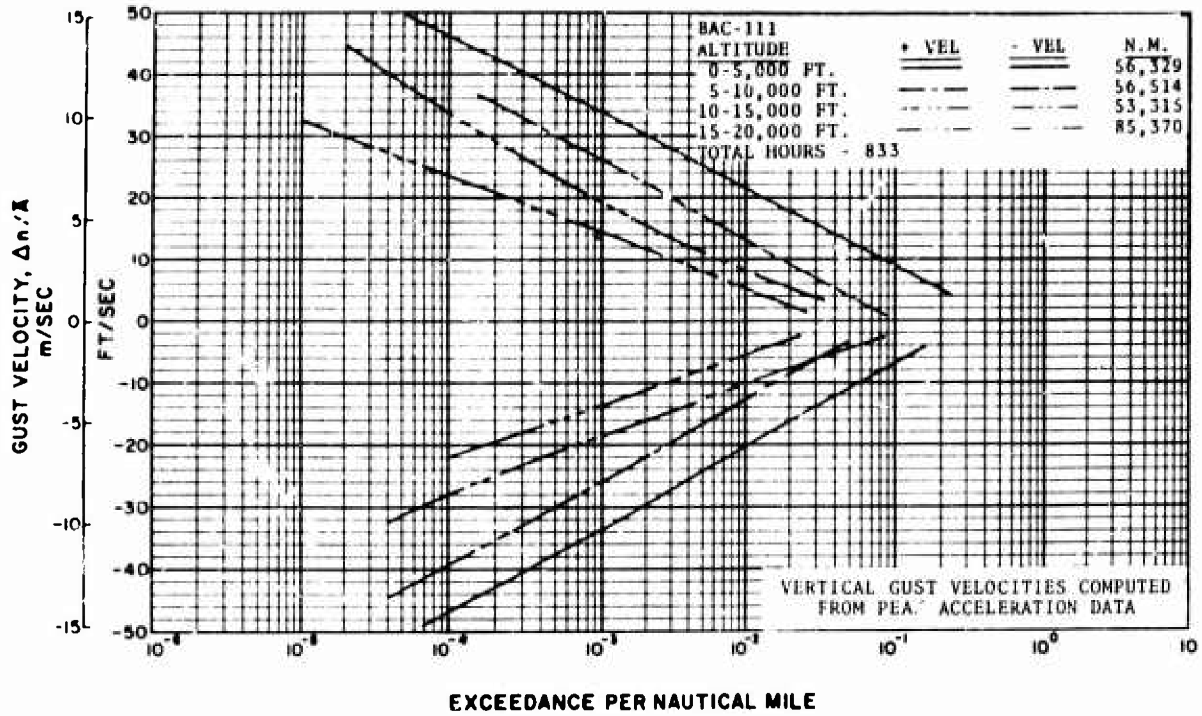

CARAVELLE
ALTITUDE
+ VEL
- VEL
N.M.
0-5,000 FT.
23,902
5-10,000 FT.
25,406
10-15,000 FT.
22,785
15-20,000 FT.
25,983
TOTAL HOURS - 360
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

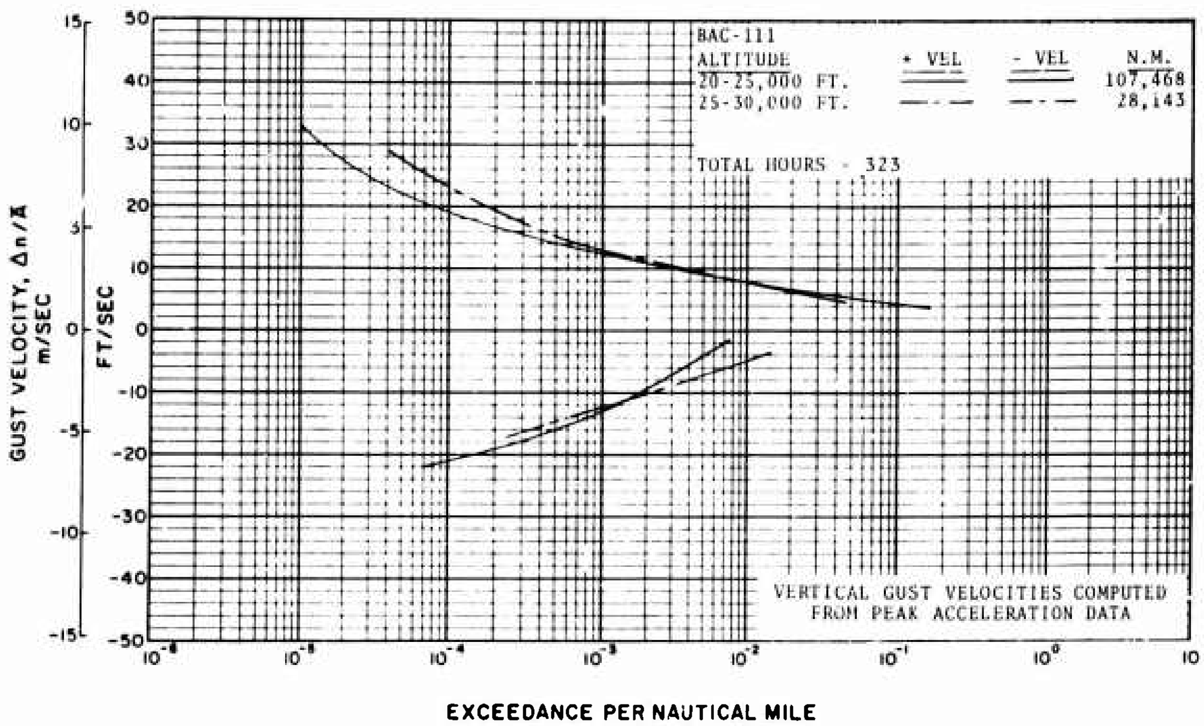

CARAVELLE
ALTITUDE
+ VEL
- VEL
N.M.
20-25,000 FT.
37,889
25-30,000 FT.
55,397
30-35,000 FT.
46,783
TOTAL HOURS - 363
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

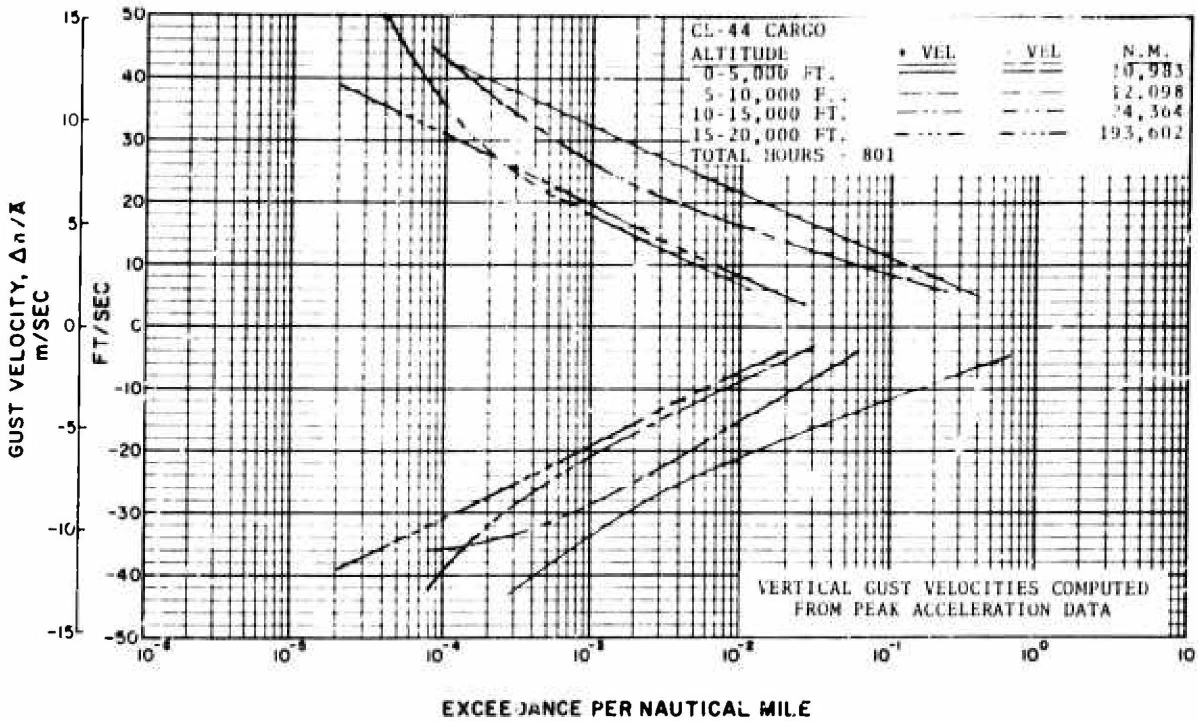

727-200
ALTITUDE
+ VEL
- VEL
N.M.
0-5,000 FT.
32,672
5-10,000 FT.
30,356
10-15,000 FT.
28,560
15-20,000 FT.
46,044
TOTAL HOURS - 445
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

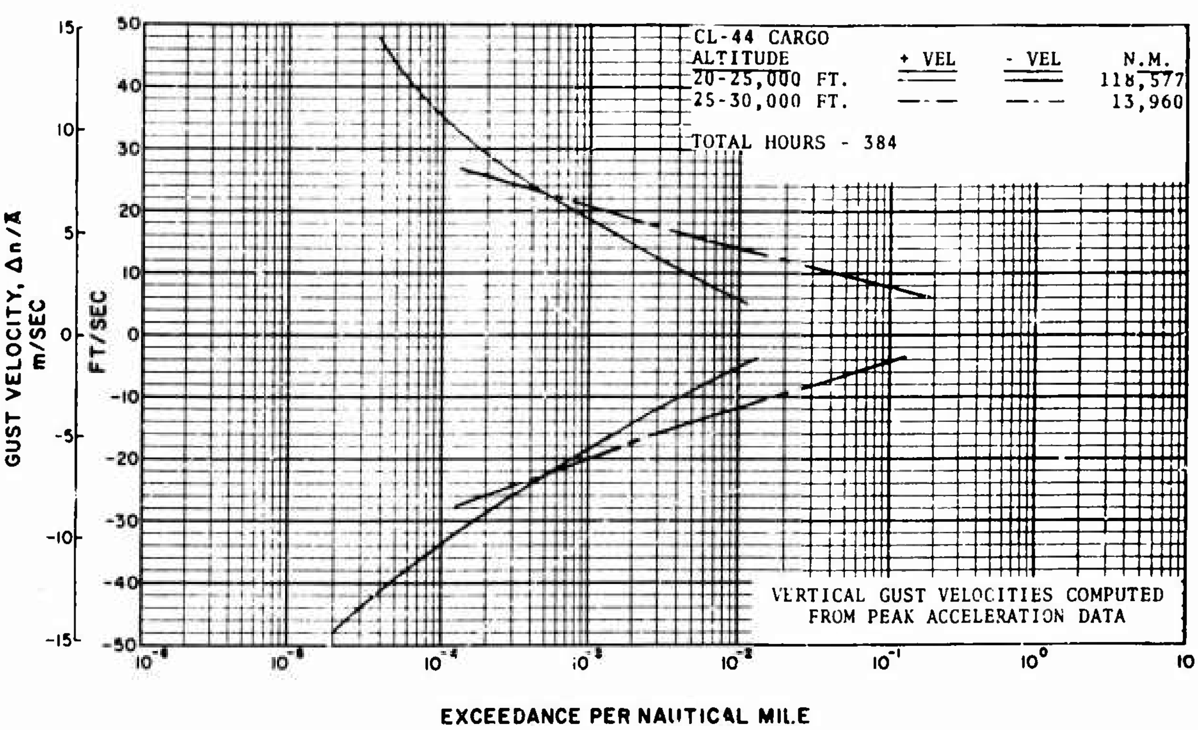

727-200
ALTITUDE
+ VEL
- VEL
N.M.
20-25,000 FT.
66,546
25-30,000 FT.
94,451
30-35,000 FT.
97,615
35-40,000 FT.
5,317
TOTAL HOURS - 549
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

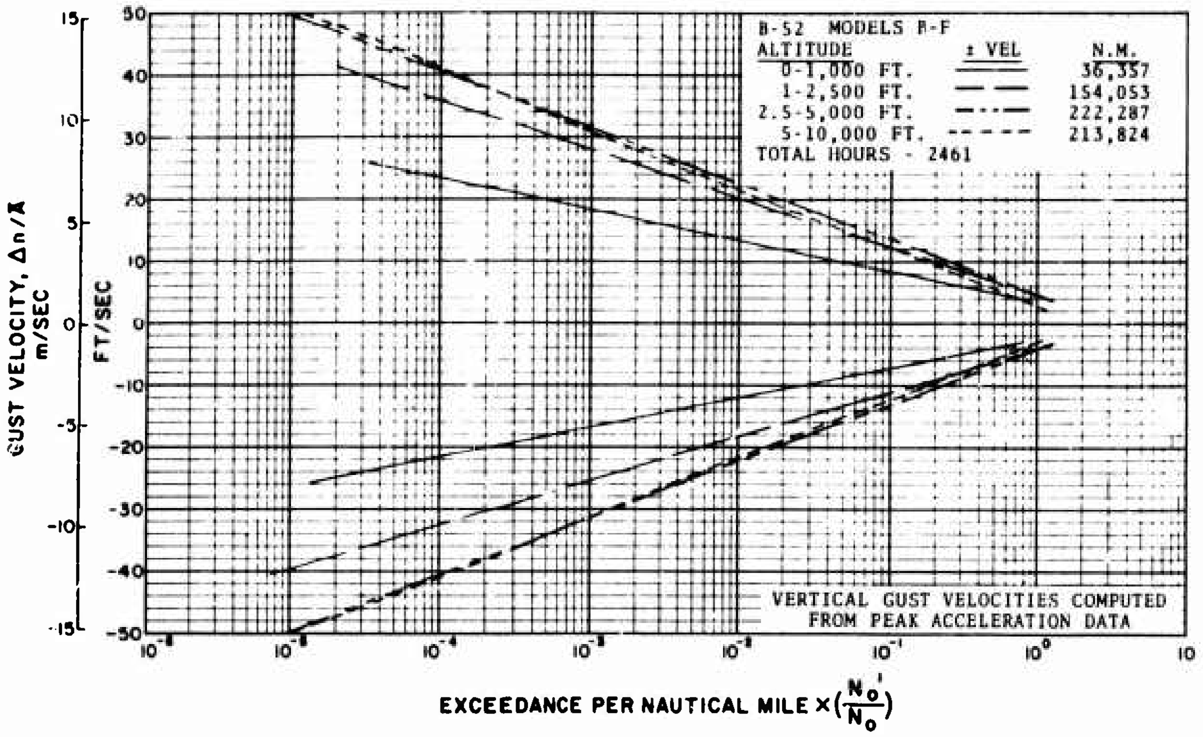

DC-7C
ALTITUDE
+ VEL
- VEL
N.M.
0-5,000 FT.
22,414
5-10,000 FT.
43,121
10-15,000 FT.
325,112
15-20,000 FT.
29,915
20-25,000 FT.
8,398
TOTAL HOURS - 1729
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE
15
10
5
0
-5
-10
-15
50
40
30
20
10
0
-10
-20
-30
-40
-50
10

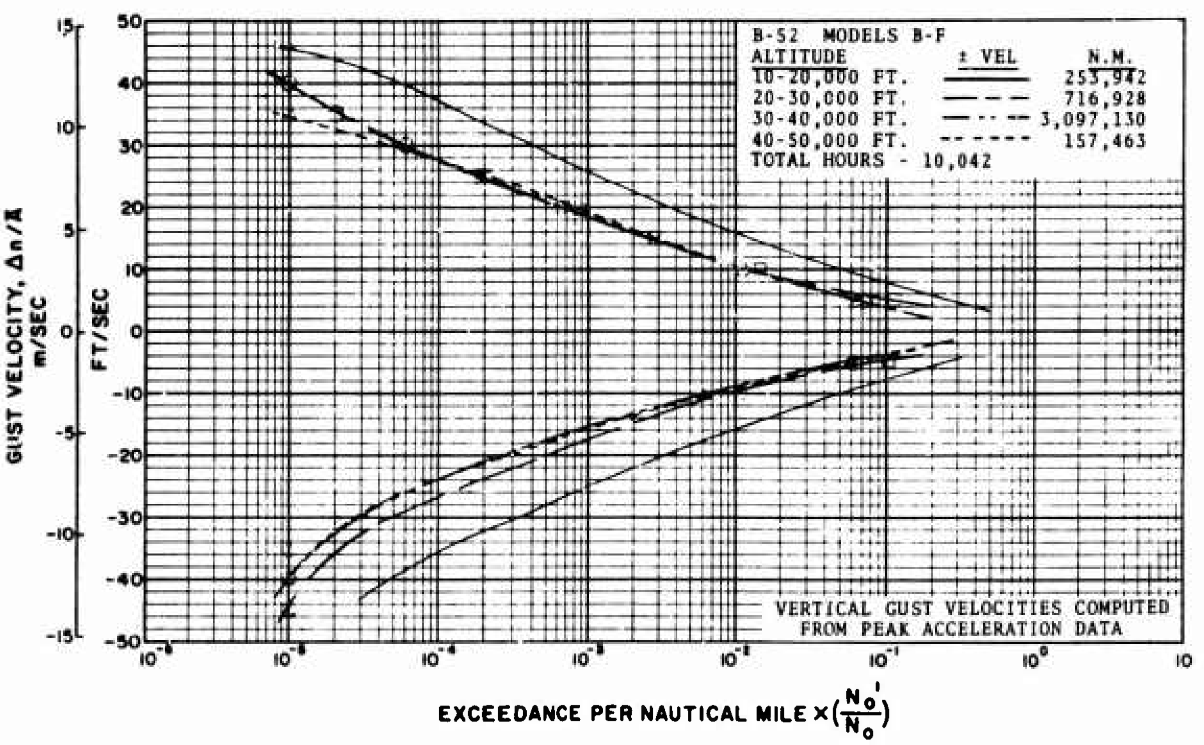

BAC-111
ALTITUDE
+ VEL
- VEL
N.M.
0-5,000 FT.
56,329
5-10,000 FT.
56,514
10-15,000 FT.
53,315
15-20,000 FT.
85,370
TOTAL HOURS - 833
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

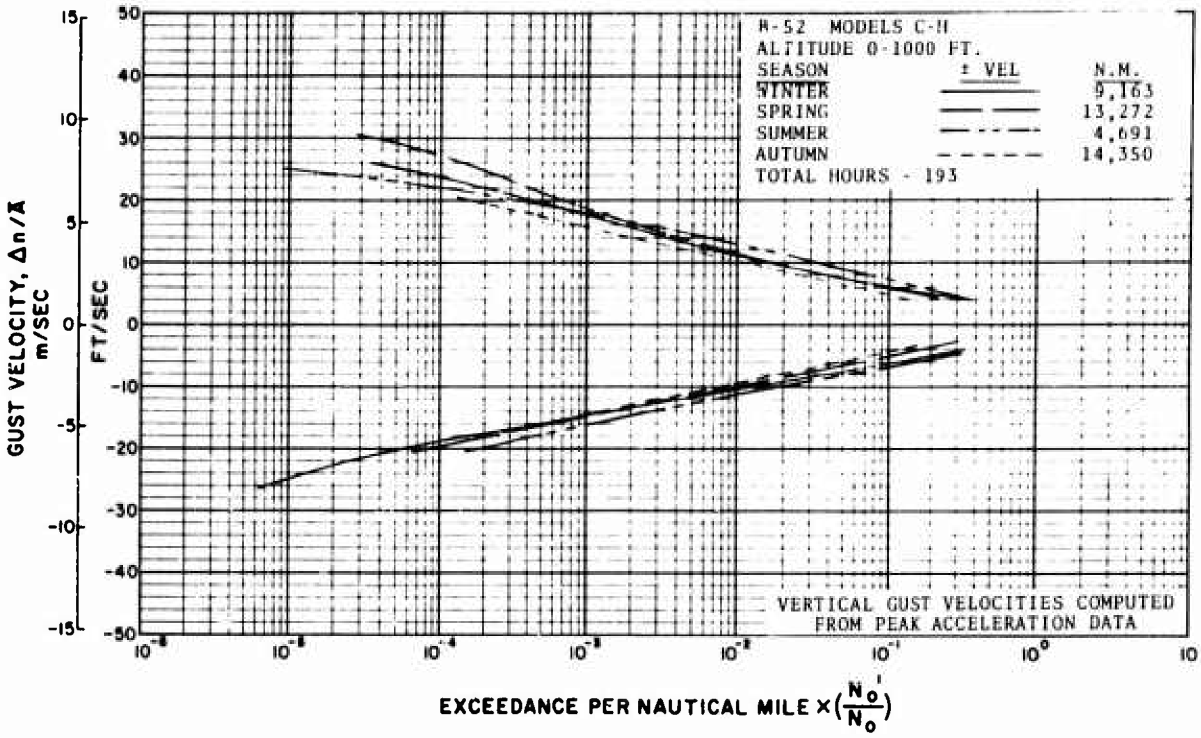

BAC-111
ALTITUDE
+ VEL
- VEL
N.M.
20-25,000 FT.
107,468
25-30,000 FT.
28,143
TOTAL HOURS - 323
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

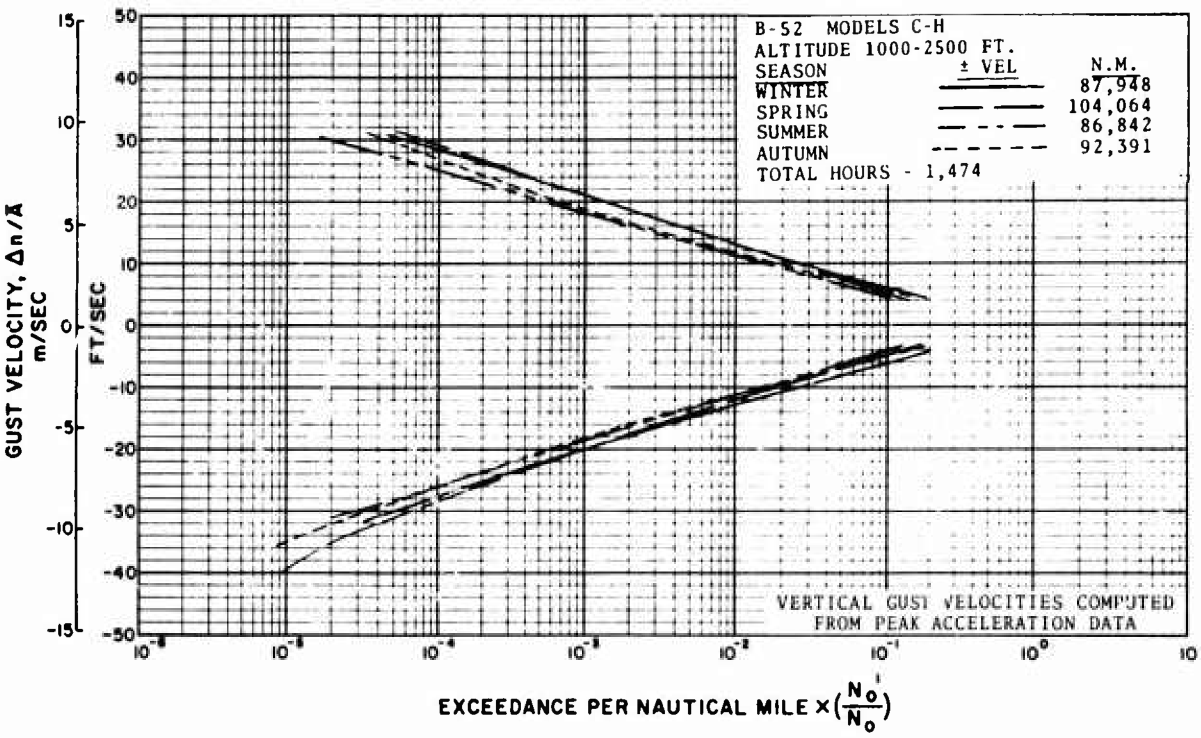

CL-44 CARGO
ALTITUDE
+ VEL
- VEL
N.M.
0-5,000 FT.
10,983
5-10,000 FT.
12,098
10-15,000 FT.
24,364
15-20,000 FT.
193,602
TOTAL HOURS - 801
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

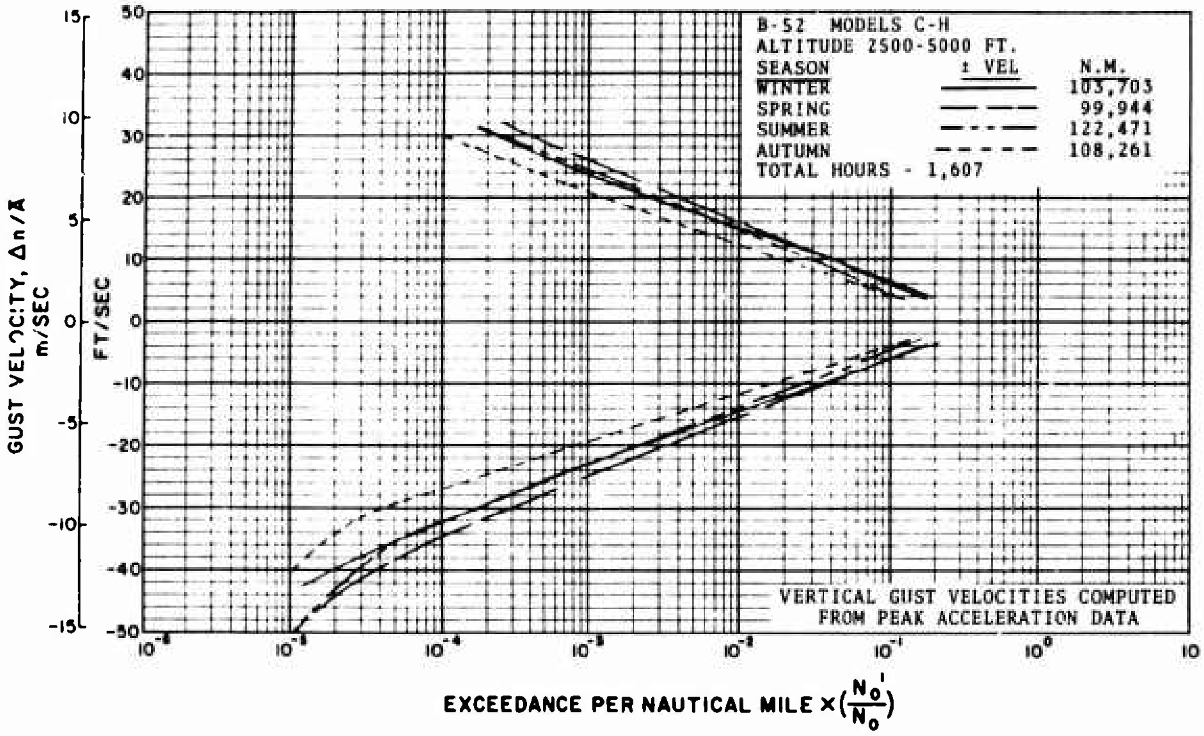

CL-44 CARGO
ALTITUDE
+ VEL
- VEL
N.M.
20-25,000 FT.
118,577
25-30,000 FT.
13,960
TOTAL HOURS - 384
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

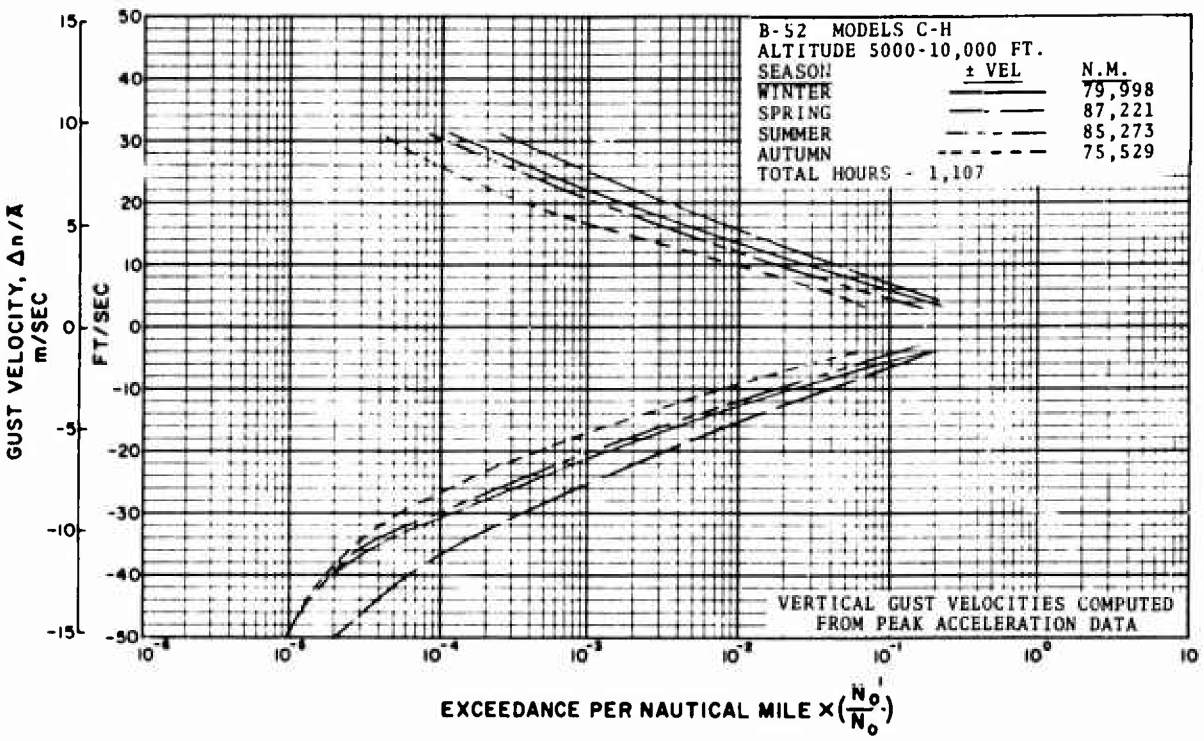

B-52 MODELS B-F
ALTITUDE ± VEL N.M.
0-1,000 FT. 36,357
1-2,500 FT. 154,053
2.5-5,000 FT. 222,287
5-10,000 FT. 213,824
TOTAL HOURS - 2461
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

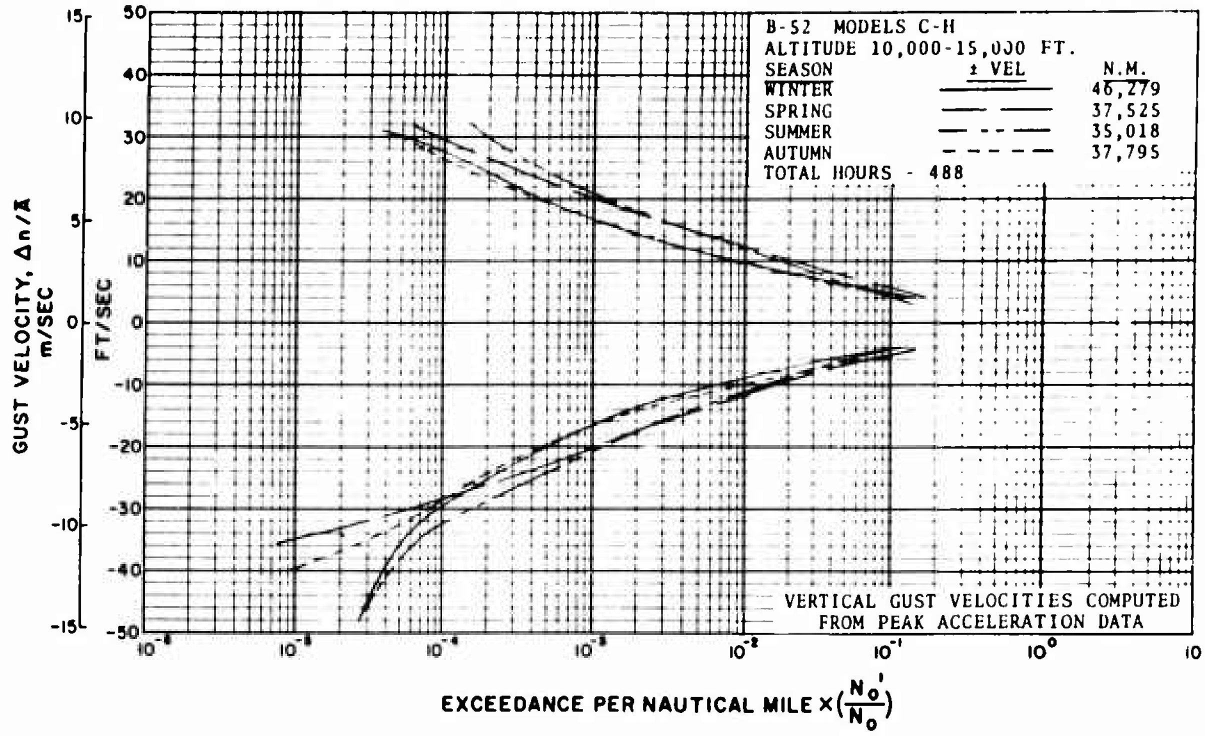

B-52 MODELS B-F
ALTITUDE ± VEL N.M.
10-20,000 FT. 253,942
20-30,000 FT. 716,928
30-40,000 FT. 3,097,130
40-50,000 FT. 157,463
TOTAL HOURS - 10,042
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

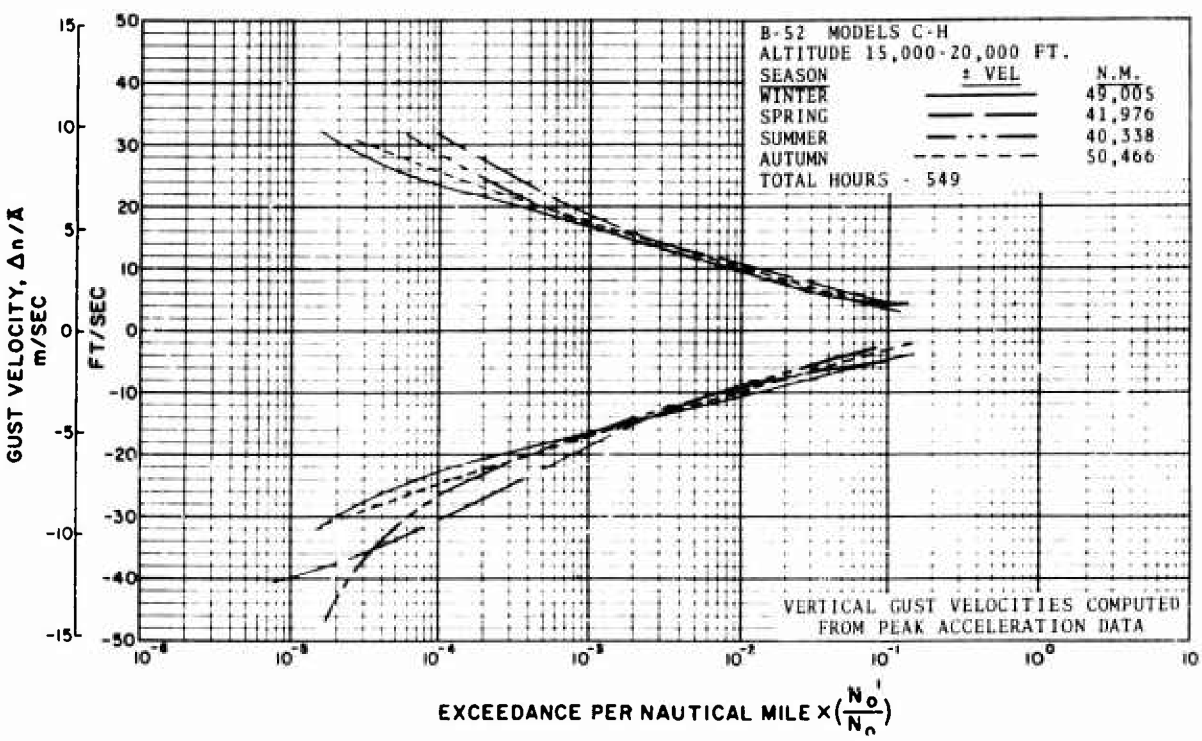

B-52 MODELS C-H
ALTITUDE 0-1000 FT.
SEASON ± VEL N.M.
WINTER 9,163
SPRING 13,272
SUMMER 4,691
AUTUMN 14,350
TOTAL HOURS - 193
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

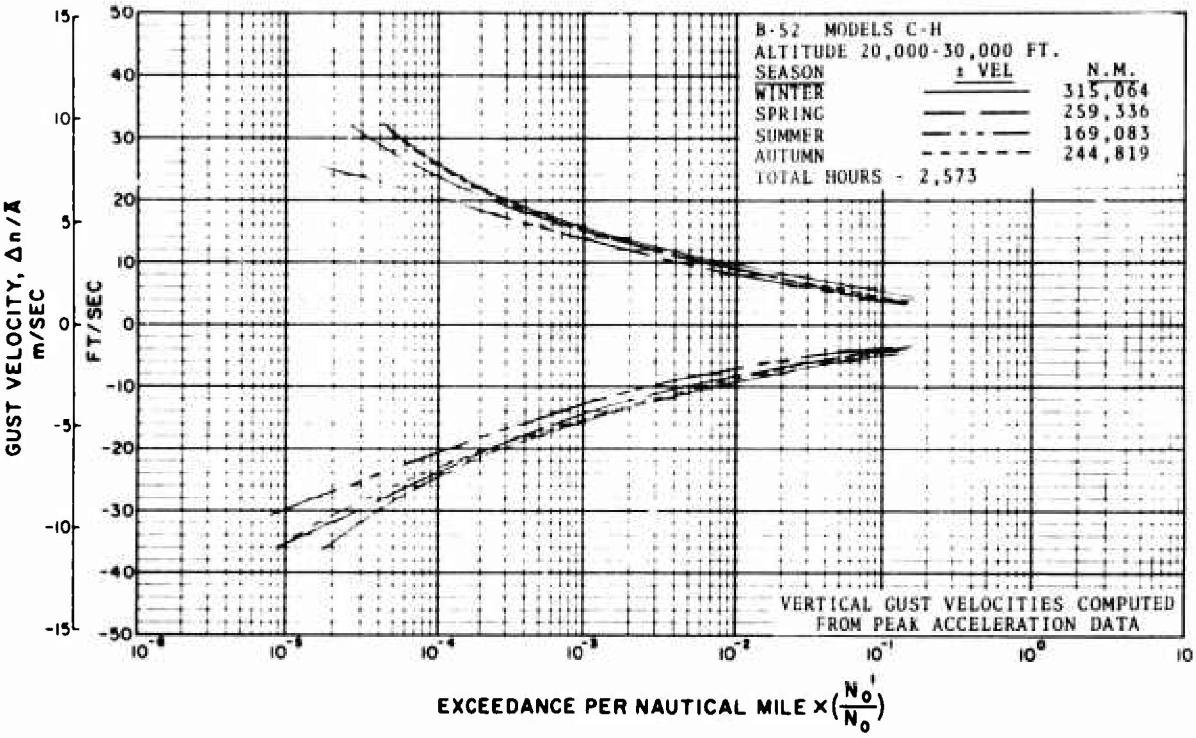

B-52 MODELS C-H
ALTITUDE 1000-2500 FT.
SEASON ± VEL N.M.
WINTER 87,948
SPRING 104,064
SUMMER 86,842
AUTUMN 92,391
TOTAL HOURS - 1,474
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × ($\frac{N_0'}{N_0}$)

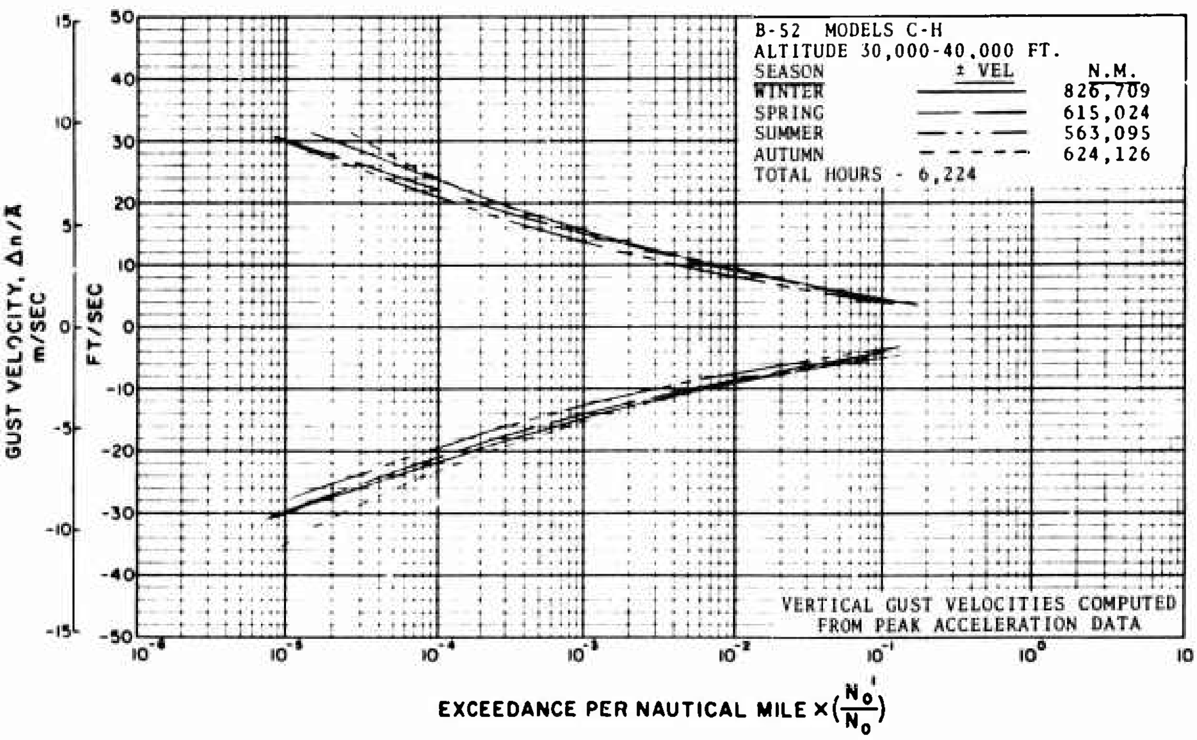

B-52 MODELS C-H
ALTITUDE 2500-5000 FT.
SEASON ± VEL N.M.
WINTER 103,703
SPRING 99,944
SUMMER 122,471
AUTUMN 108,261
TOTAL HOURS - 1,607
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

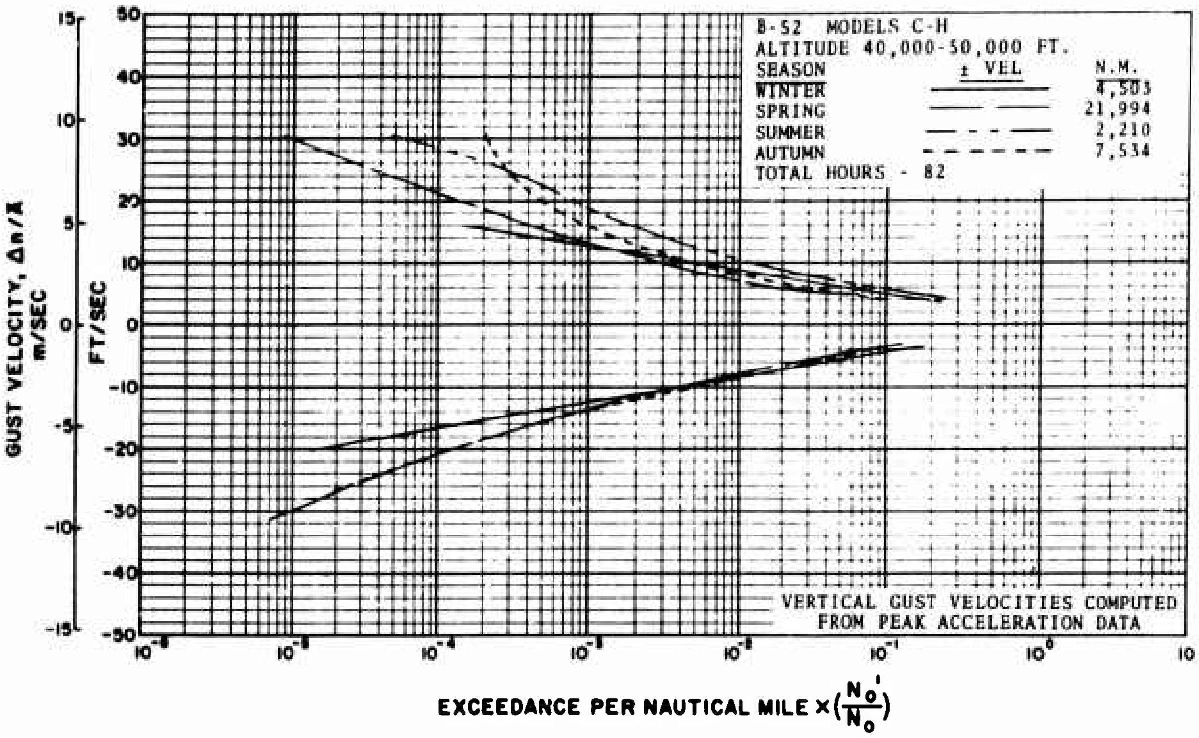

B-52 MODELS C-H
ALTITUDE 5000-10,000 FT.
SEASON ± VEL N.M.
WINTER 79,998
SPRING 87,221
SUMMER 85,273
AUTUMN 75,529
TOTAL HOURS - 1,107
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

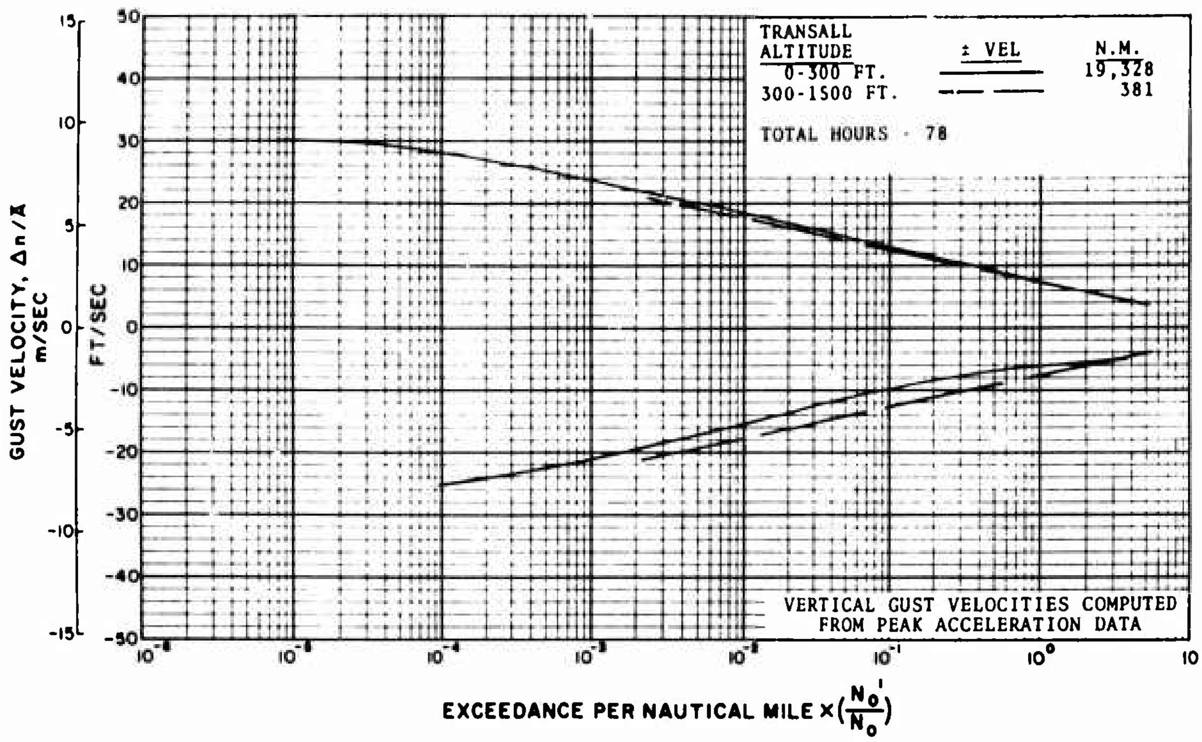

B-52 MODELS C-H
ALTITUDE 10,000-15,000 FT.
SEASON ± VEL N.M.
WINTER 46,279
SPRING 37,525
SUMMER 35,018
AUTUMN 37,795
TOTAL HOURS - 488
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)


B-52 MODELS C-H
ALTITUDE 15,000-20,000 FT.
SEASON ± VEL N.M.
WINTER 49,005
SPRING 41,976
SUMMER 40,338
AUTUMN 50,466
TOTAL HOURS - 549
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

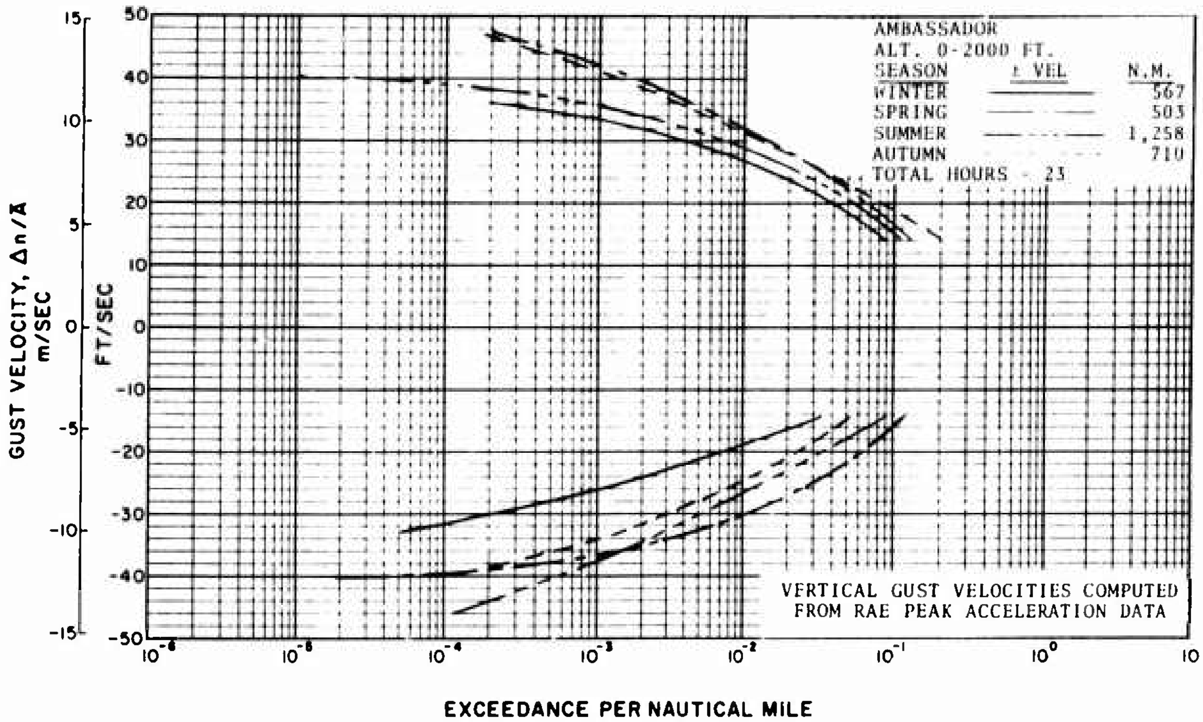

B-52 MODELS C-H
ALTITUDE 20,000-30,000 FT.
SEASON ± VEL N.M.
WINTER 315,064
SPRING 259,336
SUMMER 169,083
AUTUMN 244,819
TOTAL HOURS - 2,573
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

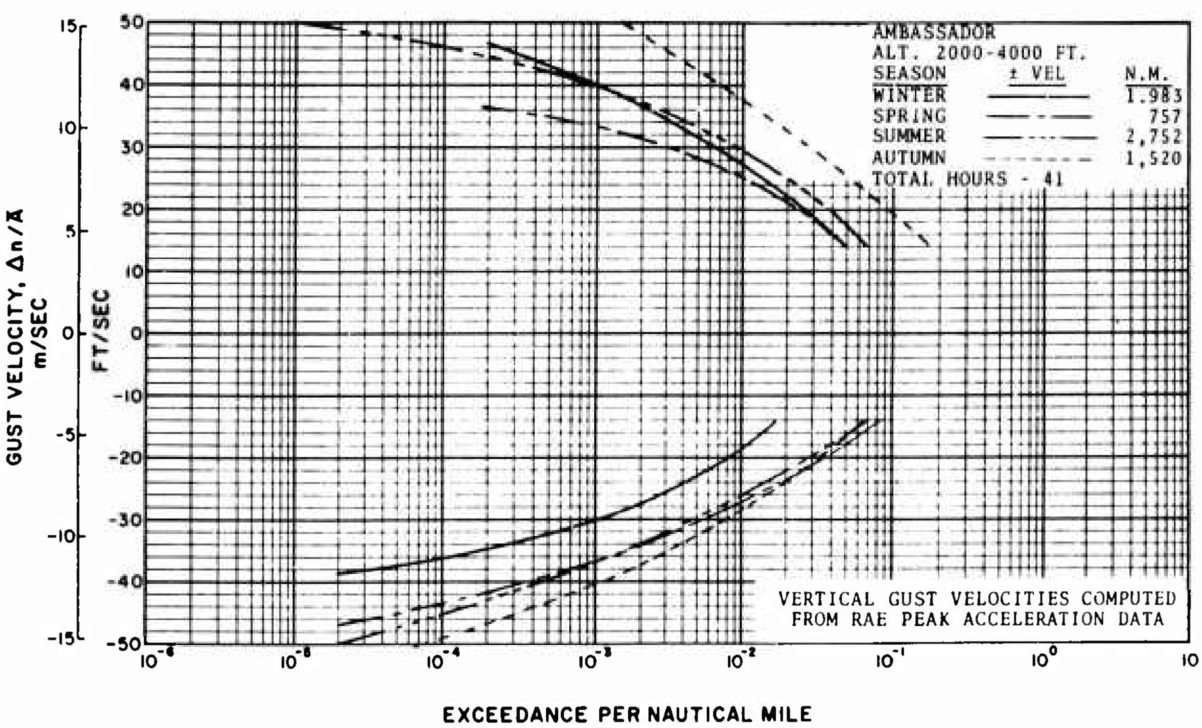

B-52 MODELS C-H
ALTITUDE 30,000-40,000 FT.
SEASON ± VEL N.M.
WINTER 826,709
SPRING 615,024
SUMMER 563,095
AUTUMN 624,126
TOTAL HOURS - 6,224
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

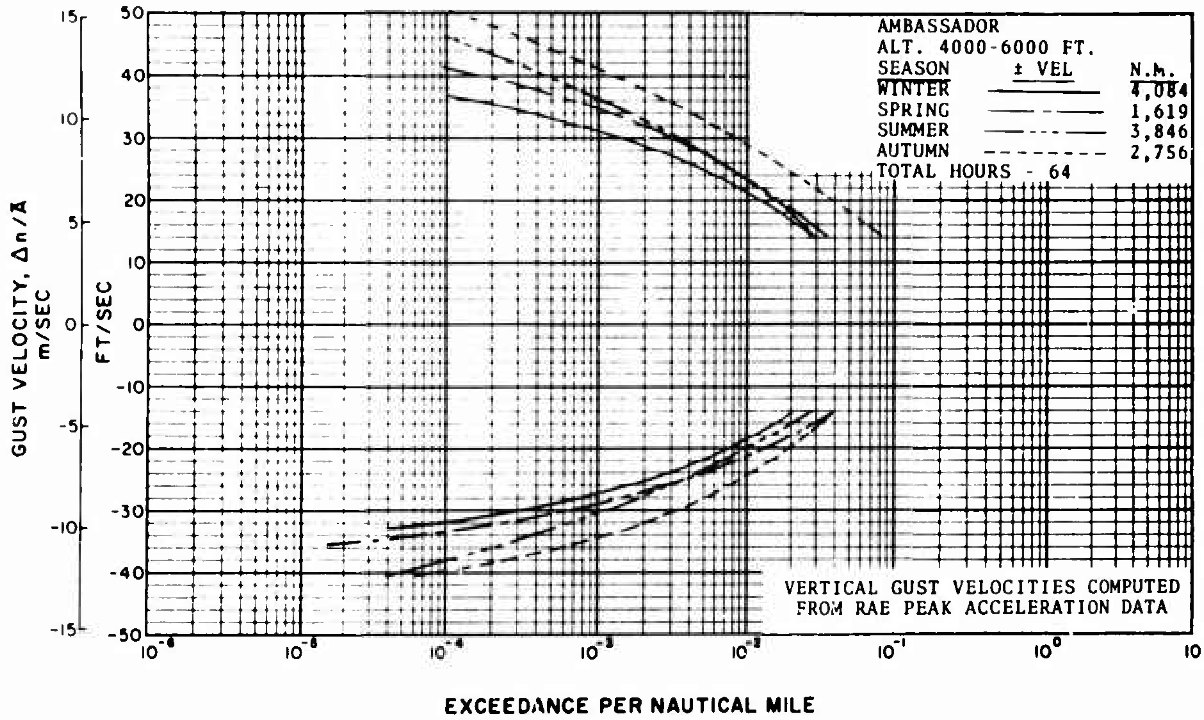

B-52 MODELS C-H
ALTITUDE 40,000-50,000 FT.
SEASON ± VEL N.M.
WINTER 4,503
SPRING 21,994
SUMMER 2,210
AUTUMN 7,534
TOTAL HOURS - 82
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/λ m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N₀'/N₀)

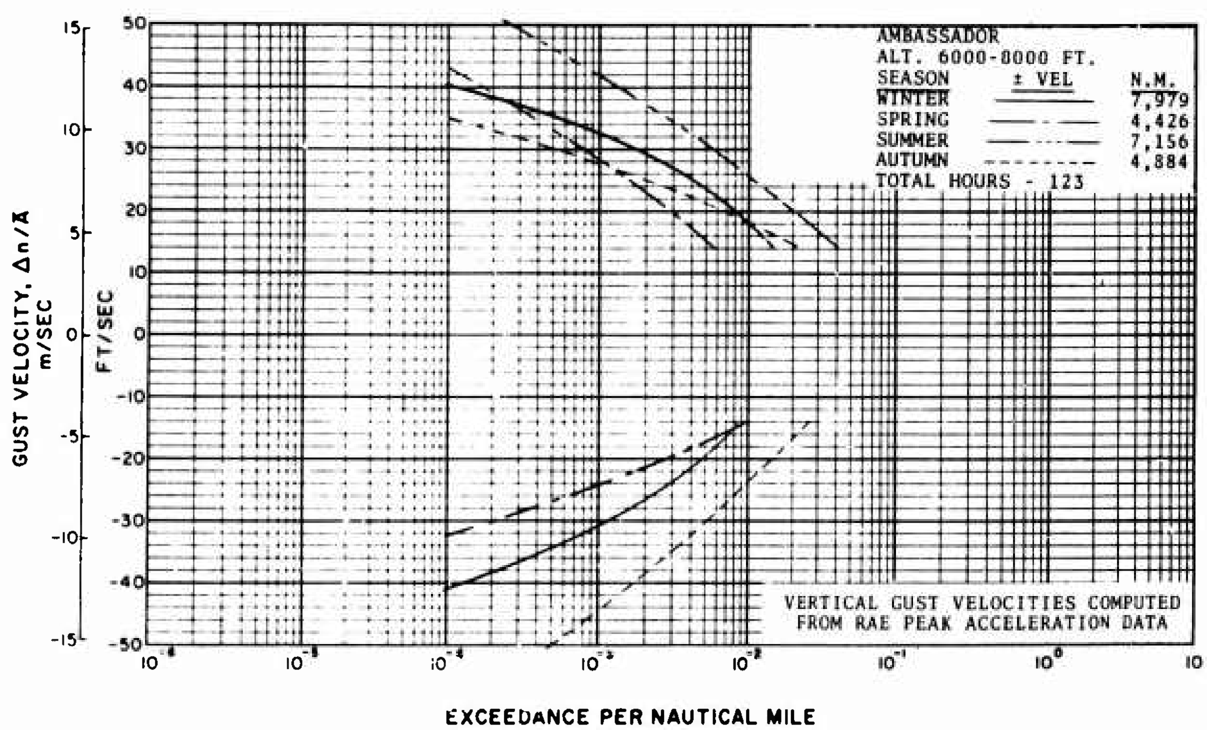


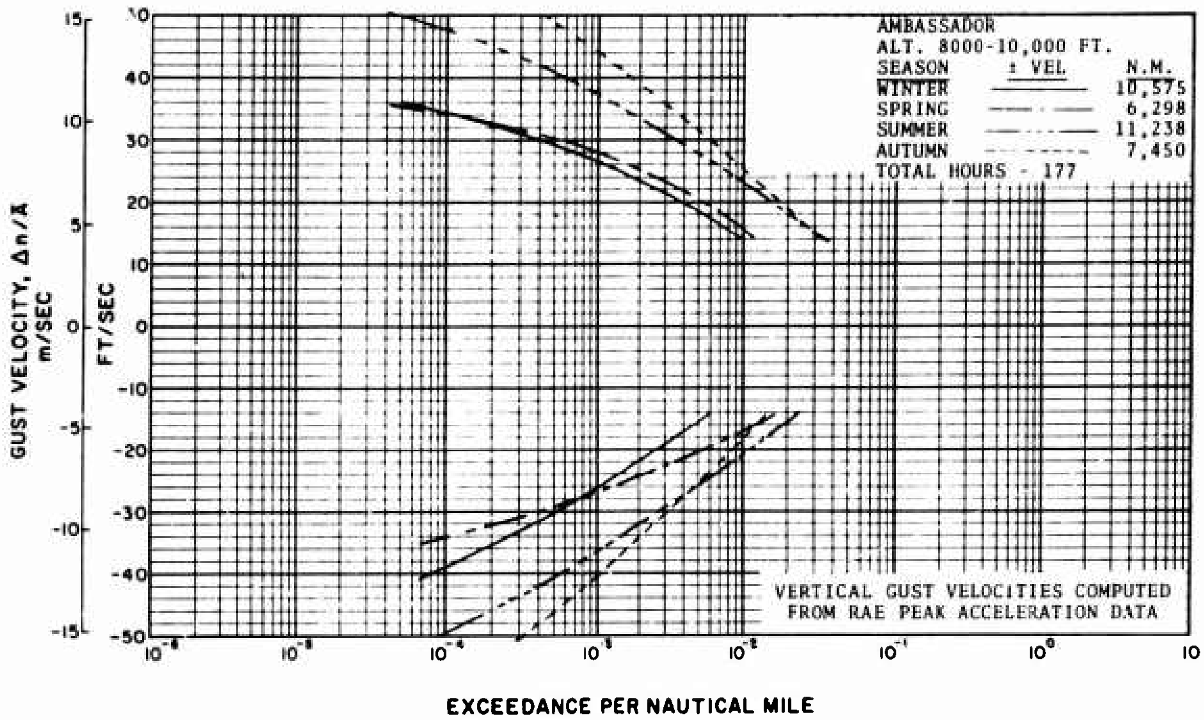
TRANSALL
ALTITUDE
0-300 FT.
300-1500 FT.
± VEL
N.M.
19,328
381
TOTAL HOURS - 78
VERTICAL GUST VELOCITIES COMPUTED FROM PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE × (N_0'/N_0)

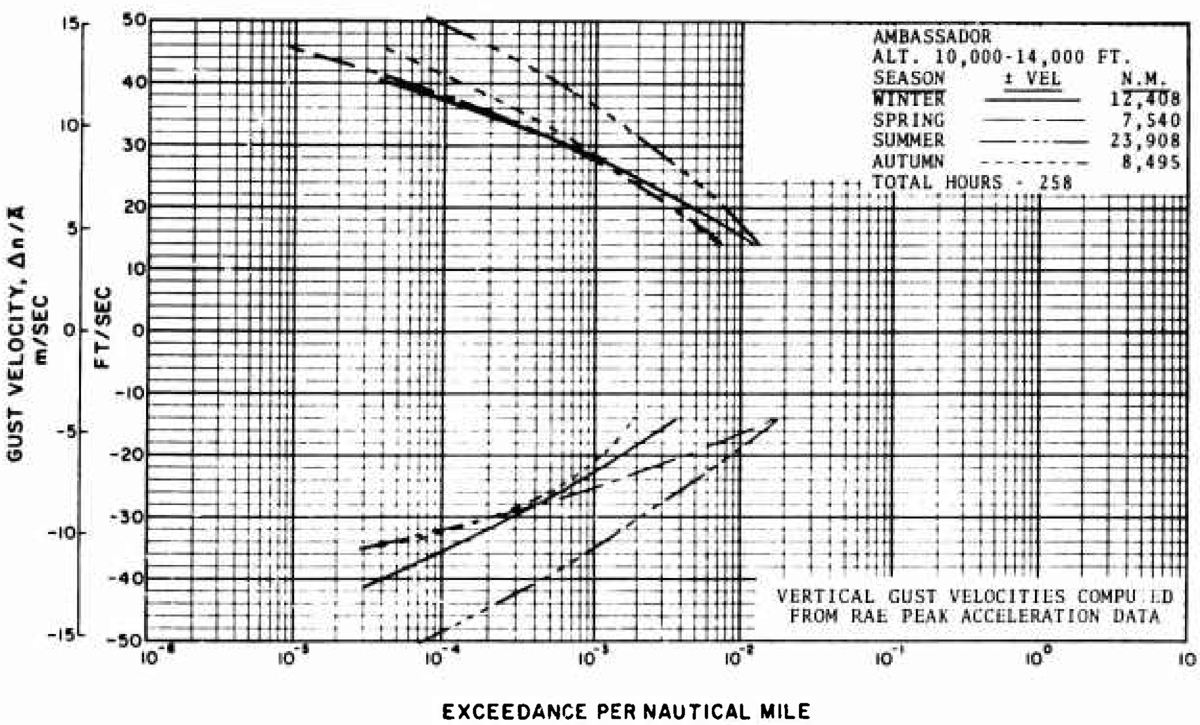

AMBASSADOR
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 567
SPRING 503
SUMMER 1,258
AUTUMN 710
TOTAL HOURS - 23
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

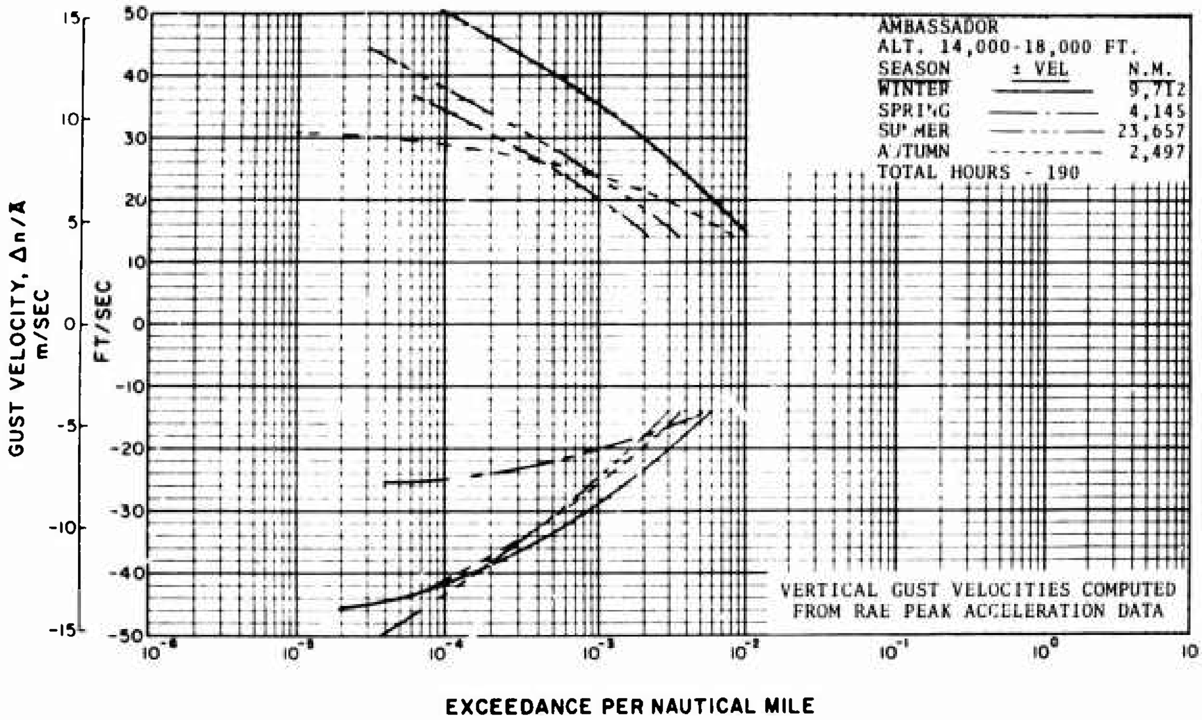

AMBASSADOR
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 1,983
SPRING 757
SUMMER 2,752
AUTUMN 1,520
TOTAL HOURS - 41
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

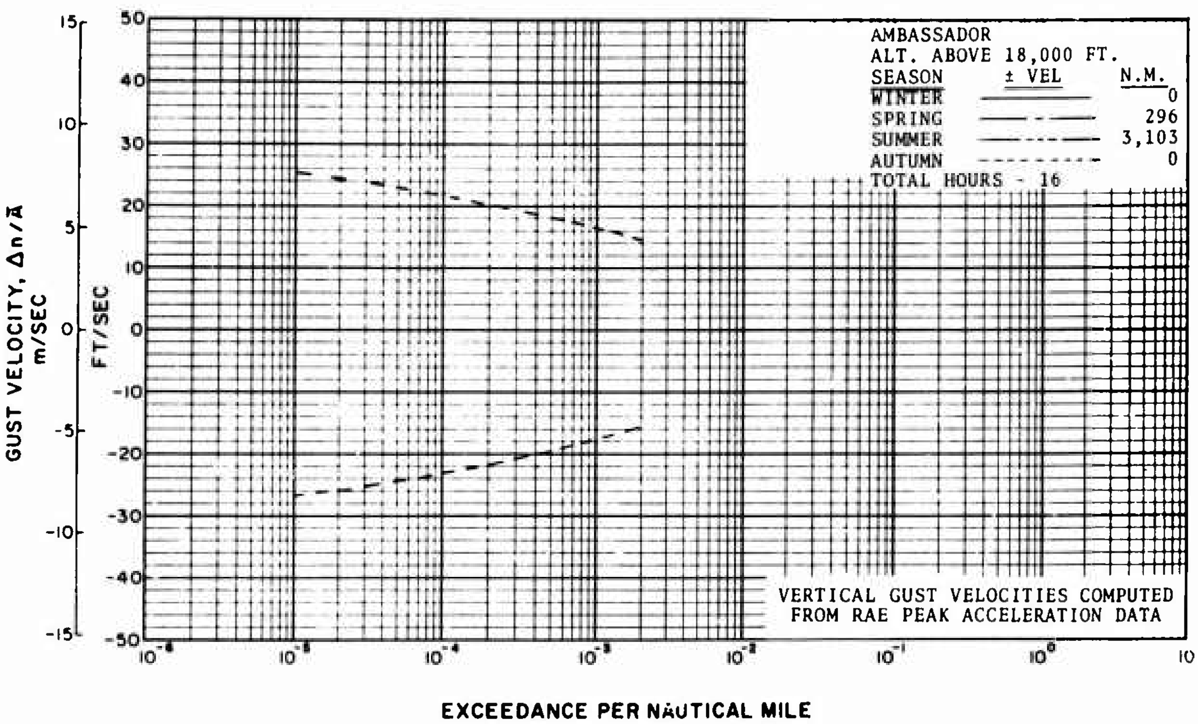

AMBASSADOR
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 4,084
SPRING 1,619
SUMMER 3,846
AUTUMN 2,756
TOTAL HOURS - 64
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

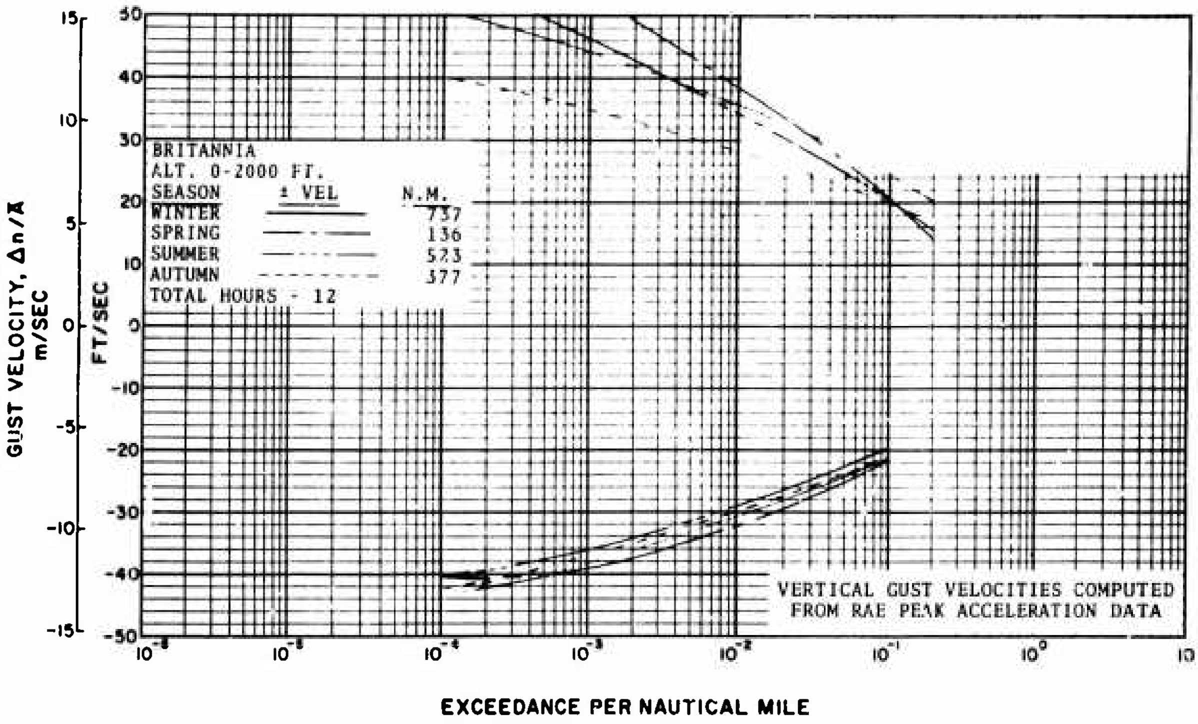

AMBASSADOR
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 7,979
SPRING 4,426
SUMMER 7,156
AUTUMN 4,884
TOTAL HOURS - 123
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

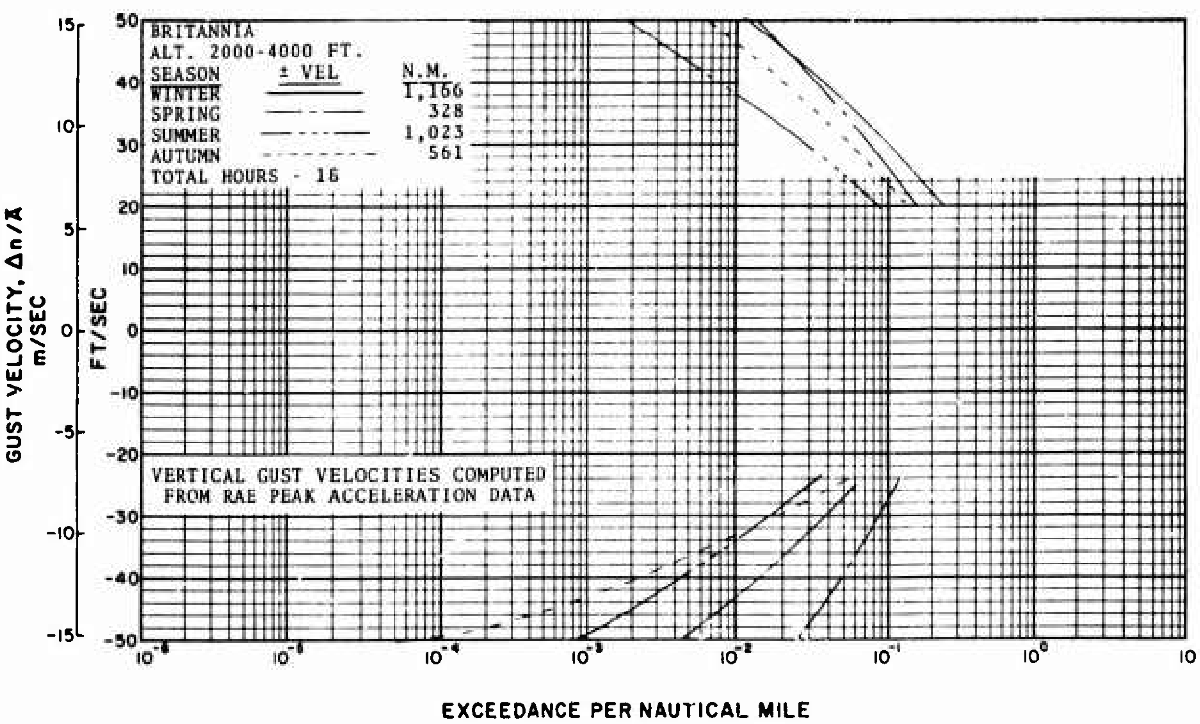

AMBASSADOR
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 10,575
SPRING 6,298
SUMMER 11,238
AUTUMN 7,450
TOTAL HOURS - 177
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

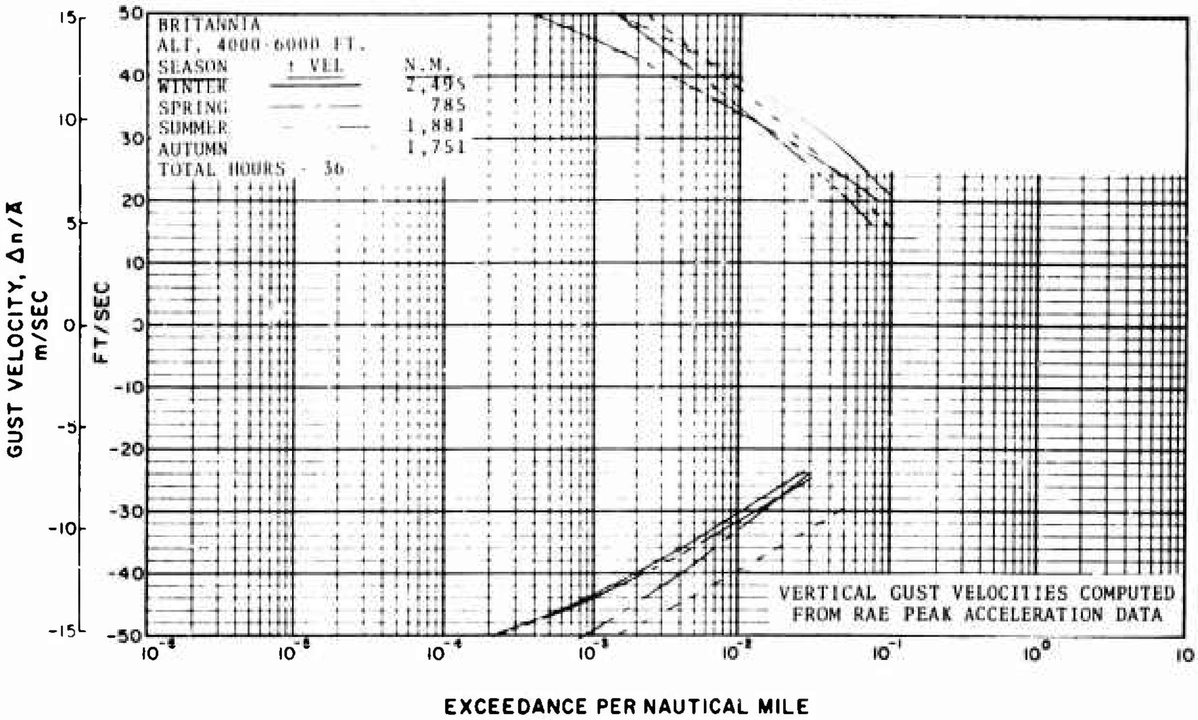

AMBASSADOR
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 12,408
SPRING 7,540
SUMMER 23,908
AUTUMN 8,495
TOTAL HOURS - 258
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

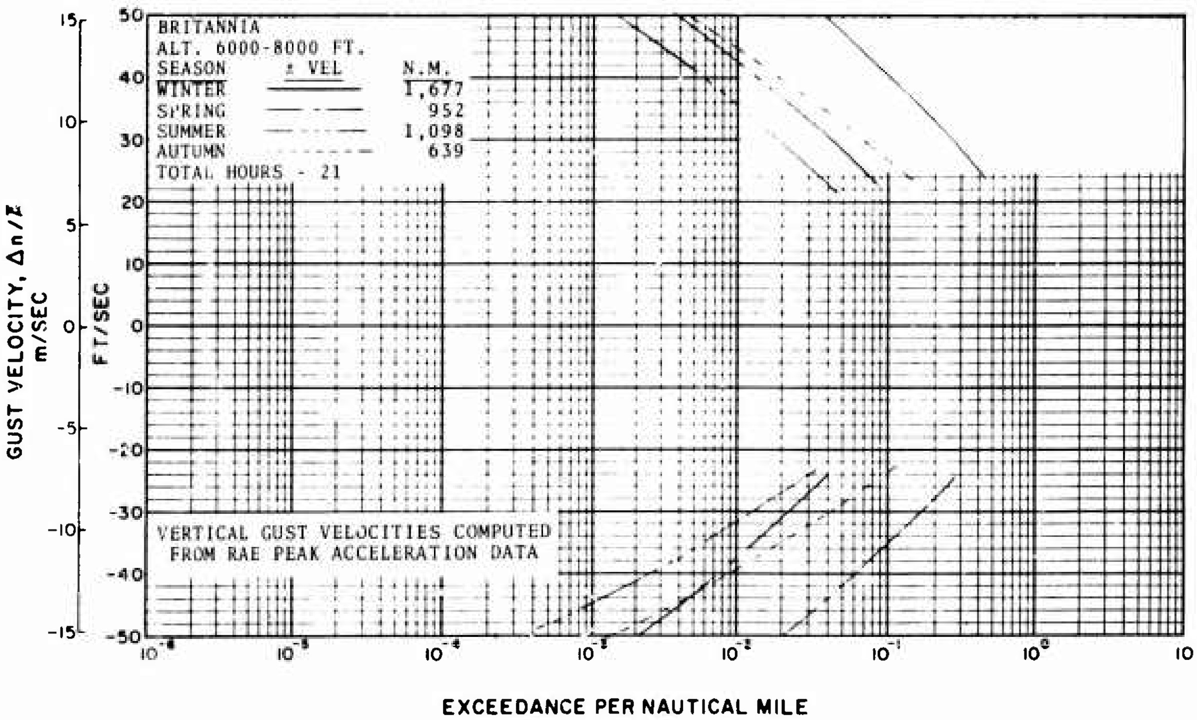

AMBASSADOR
ALT. 14,000-18,000 FT.
SEASON ± VEL N.M.
WINTER 9,712
SPRING 4,145
SUMMER 23,657
AUTUMN 2,497
TOTAL HOURS - 190
VERTICAL GUST VELOCITIES COMPUTED
FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā
m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

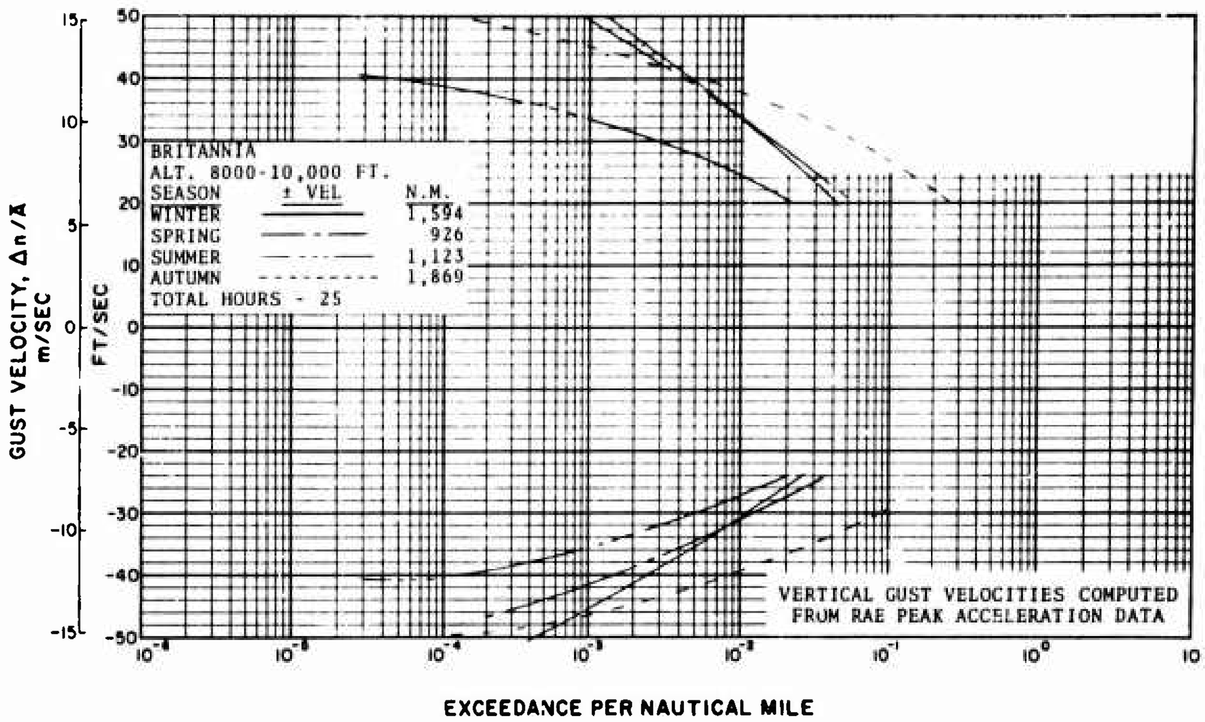

AMBASSADOR
ALT. ABOVE 18,000 FT.
SEASON ± VEL N.M.
WINTER 0
SPRING 296
SUMMER 3,103
AUTUMN 0
TOTAL HOURS - 16
VERTICAL GUST VELOCITIES COMPUTED
FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā
m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

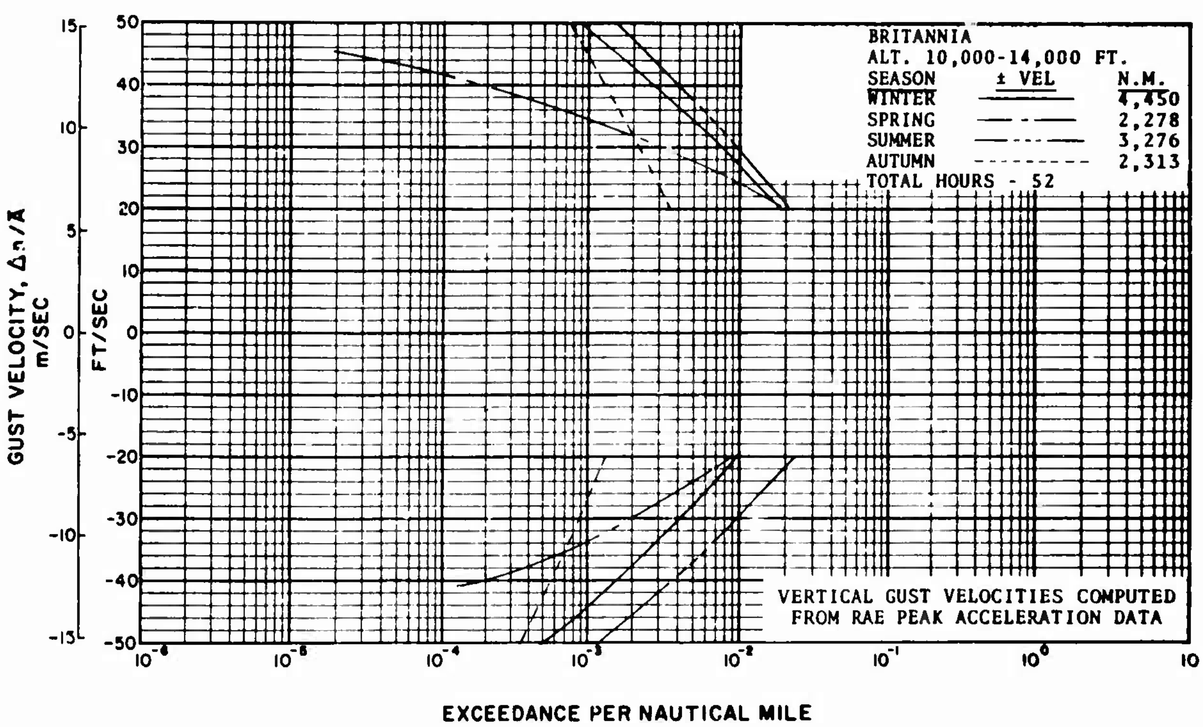

BRITANNIA
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 737
SPRING 136
SUMMER 523
AUTUMN 377
TOTAL HOURS - 12
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

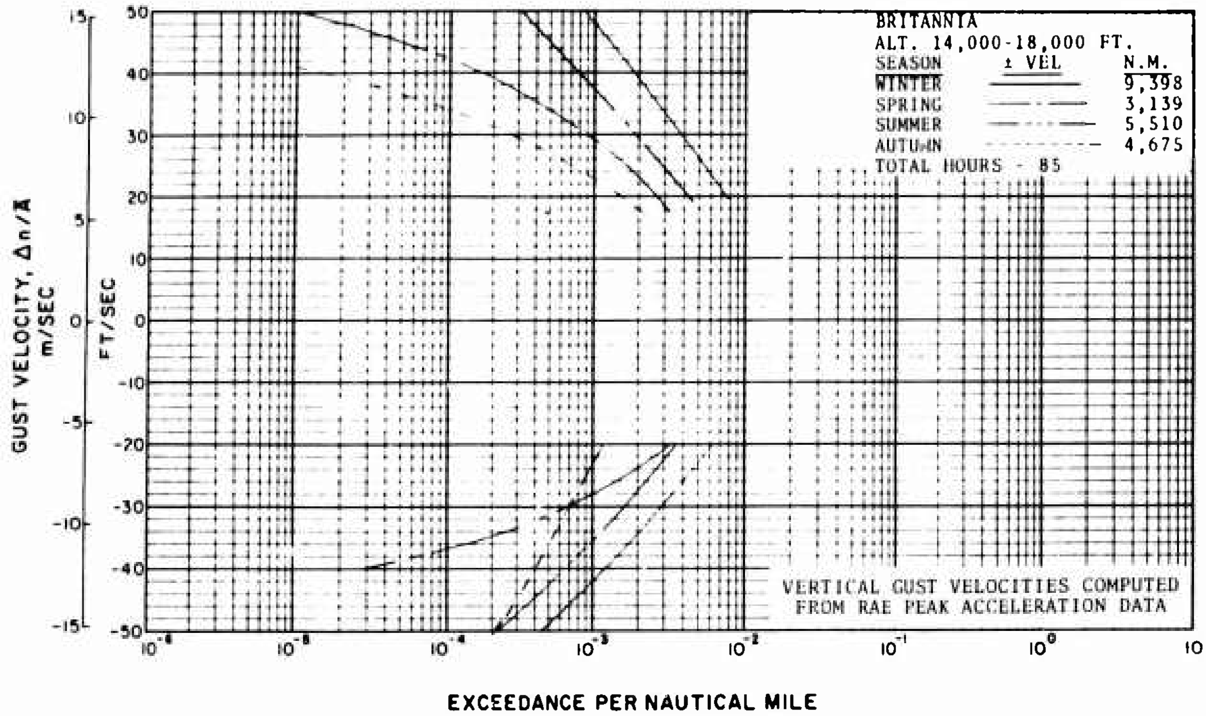

BRITANNIA
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 1,166
SPRING 328
SUMMER 1,023
AUTUMN 561
TOTAL HOURS - 16
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

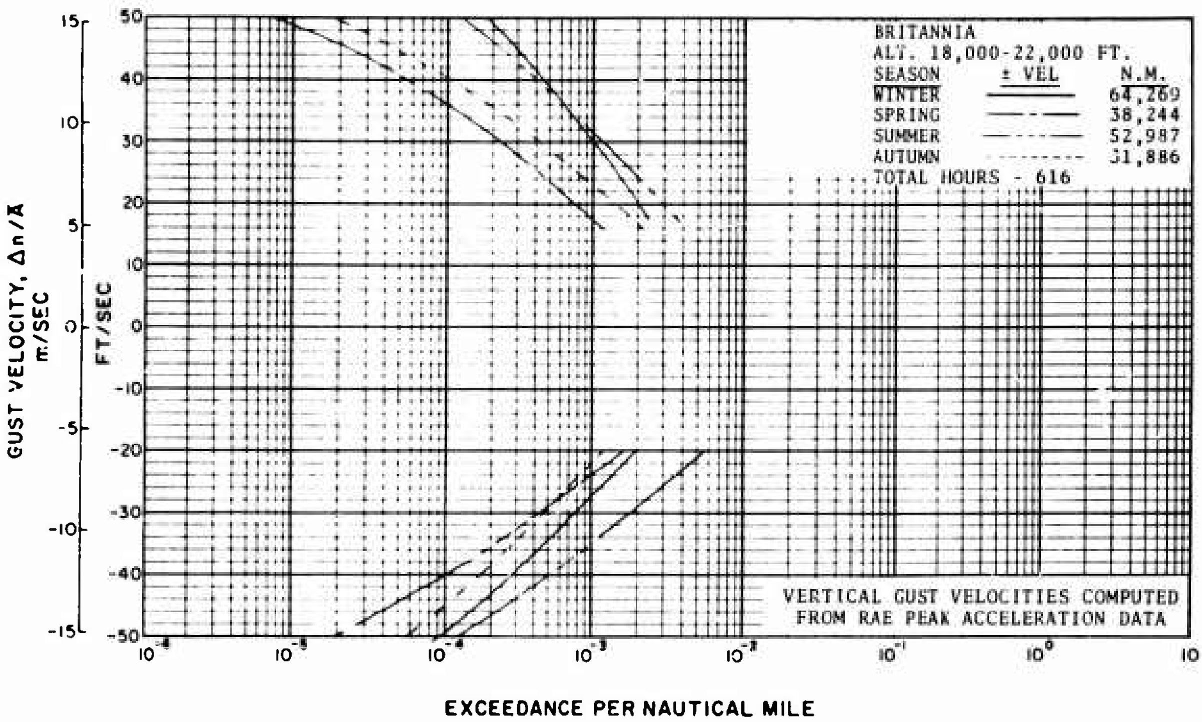

BRITANNIA
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 2,495
SPRING 785
SUMMER 1,881
AUTUMN 1,751
TOTAL HOURS - 36
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

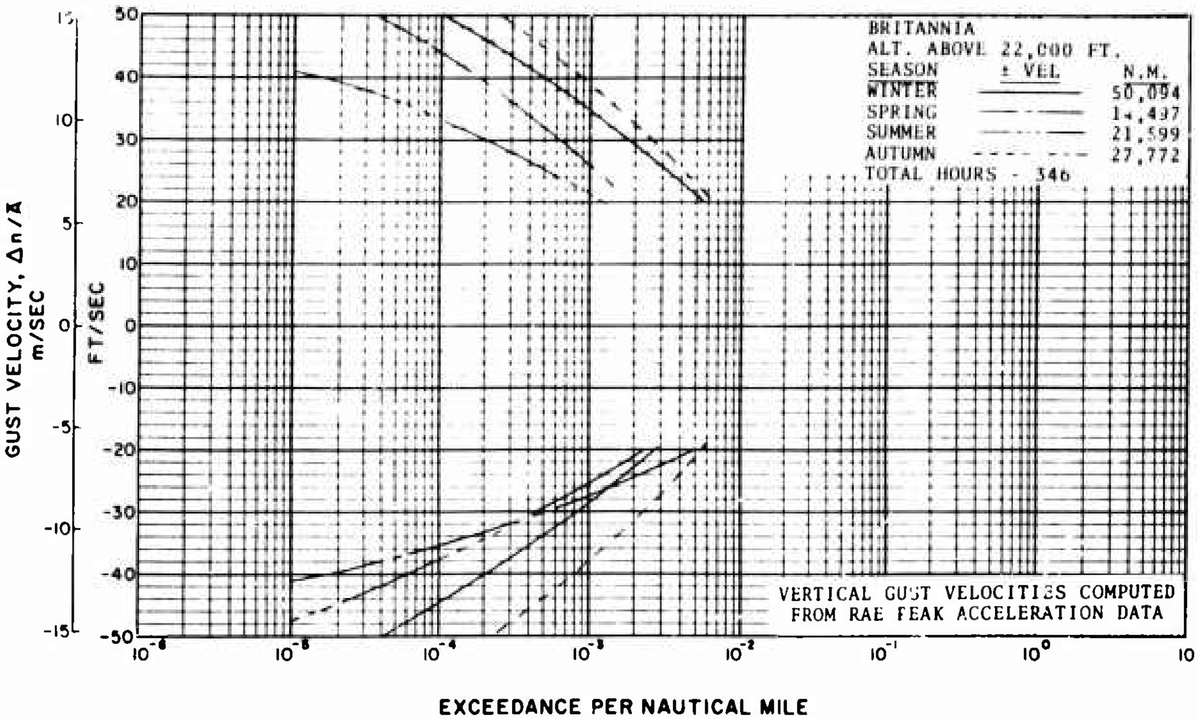

BRITANNIA
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 1,677
SPRING 952
SUMMER 1,098
AUTUMN 639
TOTAL HOURS - 21
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


BRITANNIA
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 1,594
SPRING 926
SUMMER 1,123
AUTUMN 1,869
TOTAL HOURS - 25
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

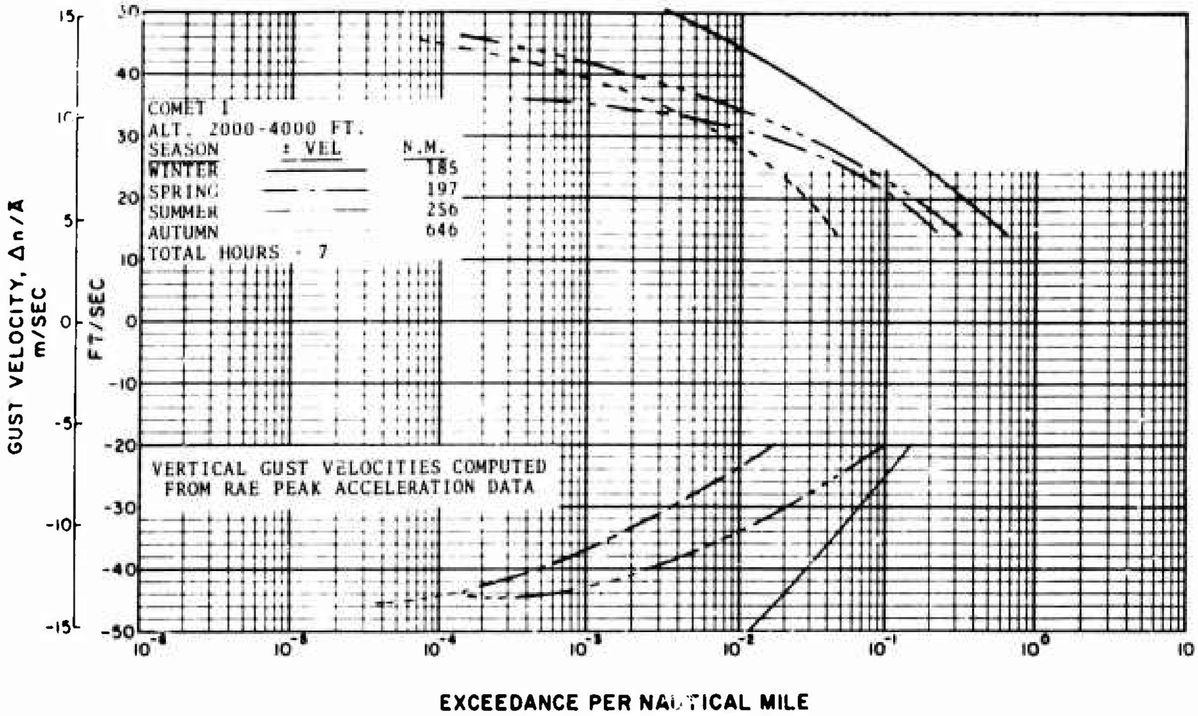

BRITANNIA
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 4,450
SPRING 2,278
SUMMER 3,276
AUTUMN 2,313
TOTAL HOURS - 52
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


BRITANNIA
ALT. 14,000-18,000 FT.
SEASON ± VEL N.M.
WINTER 9,398
SPRING 3,139
SUMMER 5,510
AUTUMN 4,675
TOTAL HOURS - 85
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

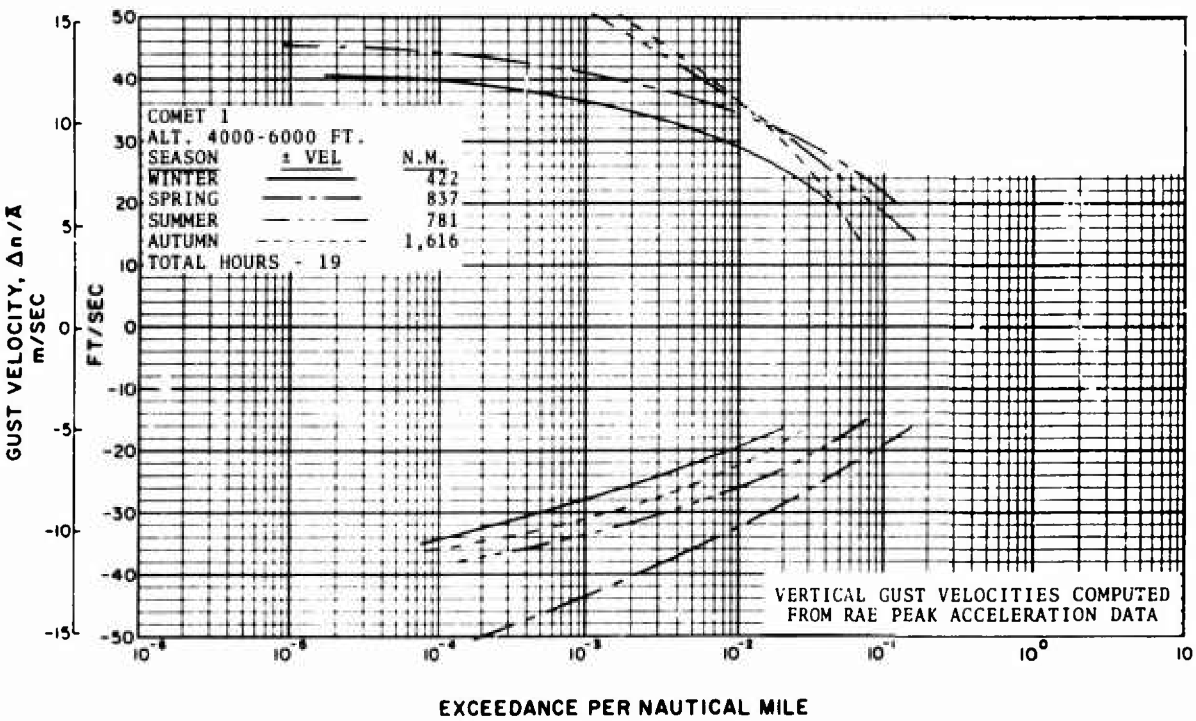

BRITANNIA
ALT. 18,000-22,000 FT.
SEASON ± VEL N.M.
WINTER 64,269
SPRING 38,244
SUMMER 52,987
AUTUMN 31,886
TOTAL HOURS - 616
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE



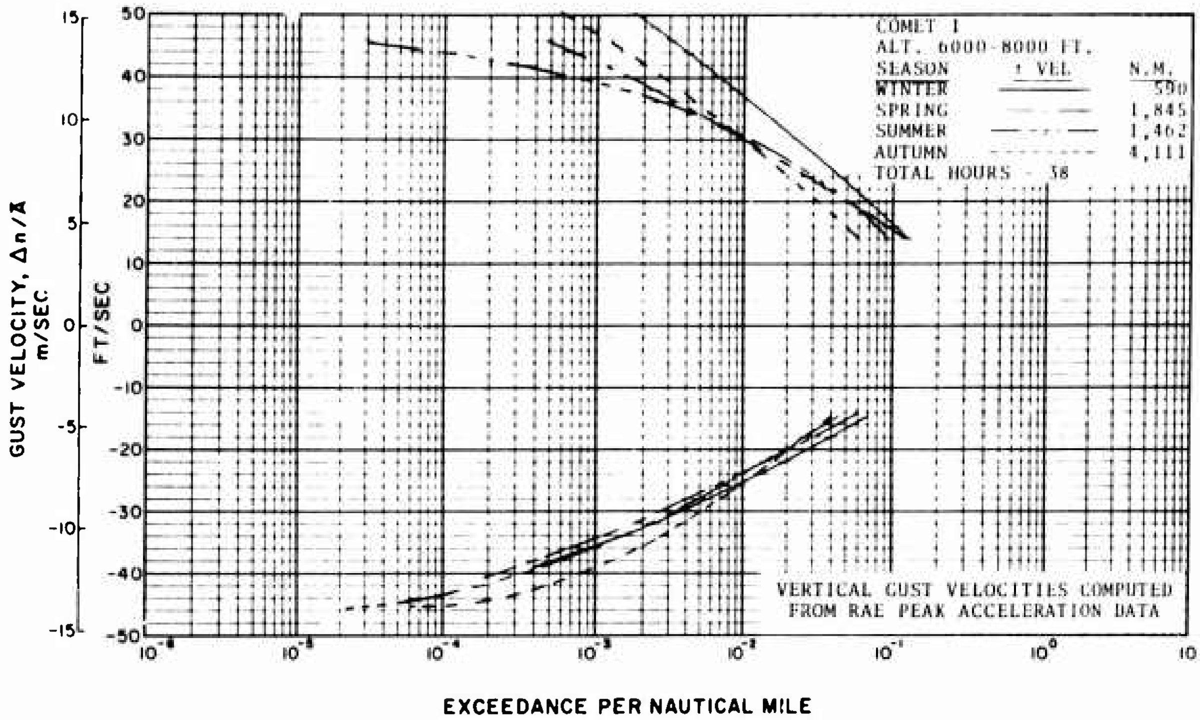
BRITANNIA
ALT. ABOVE 22,000 FT.
SEASON ± VEL N.M.
WINTER 50,094
SPRING 14,437
SUMMER 21,599
AUTUMN 27,772
TOTAL HOURS - 346
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

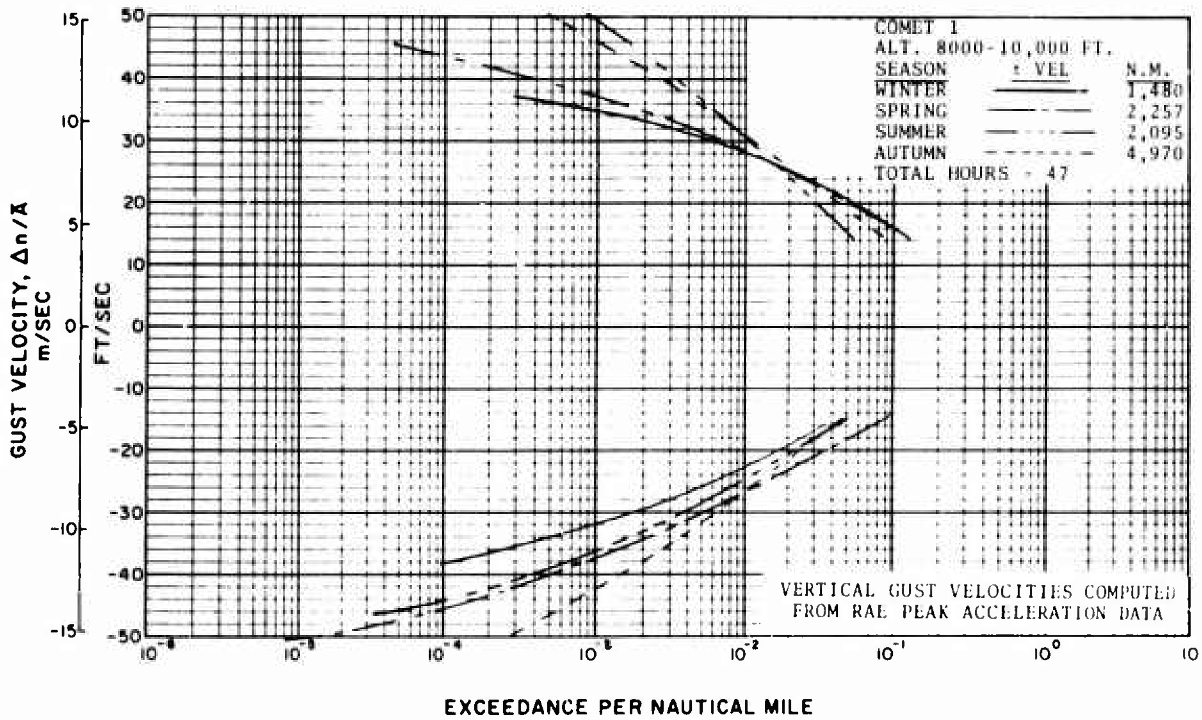


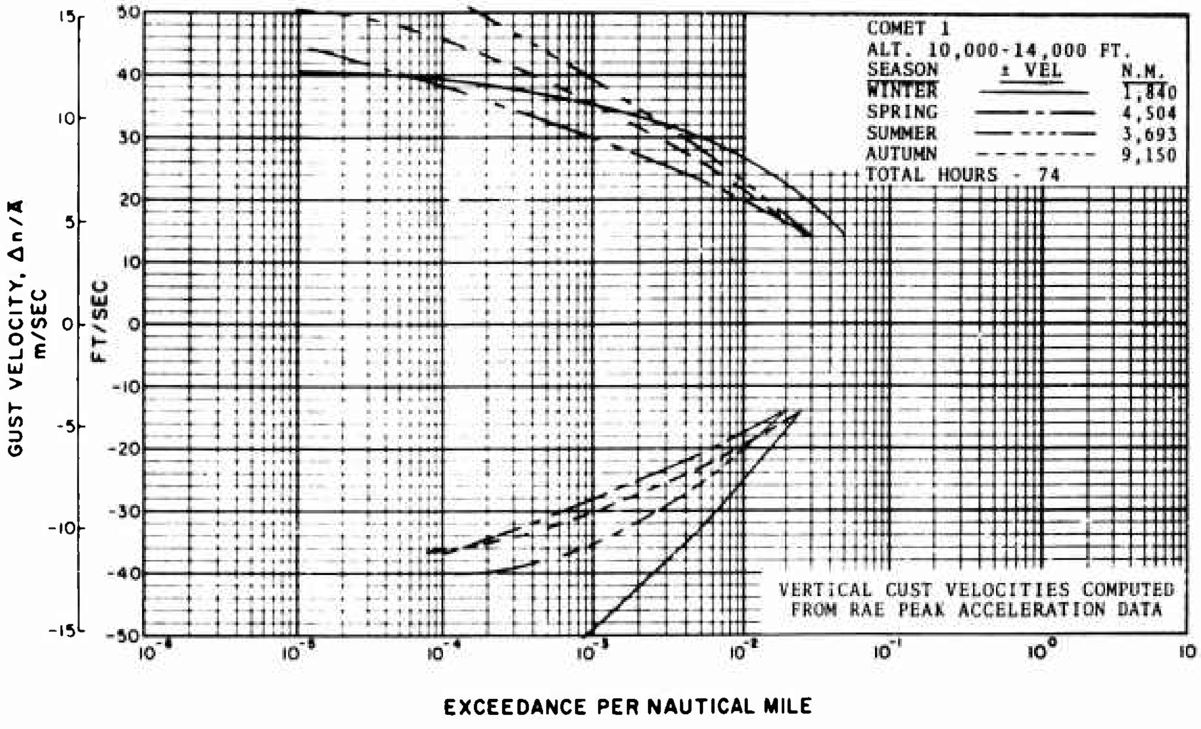
COMET 1
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 185
SPRING 197
SUMMER 256
AUTUMN 646
TOTAL HOURS - 7
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

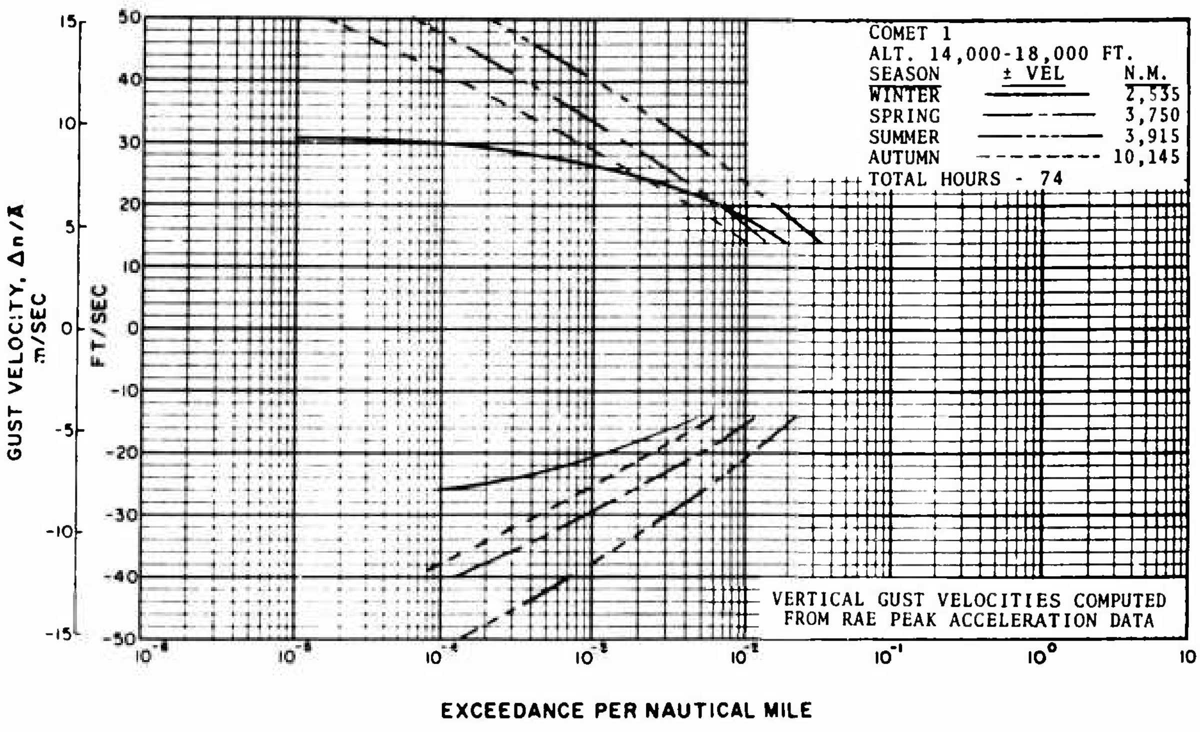


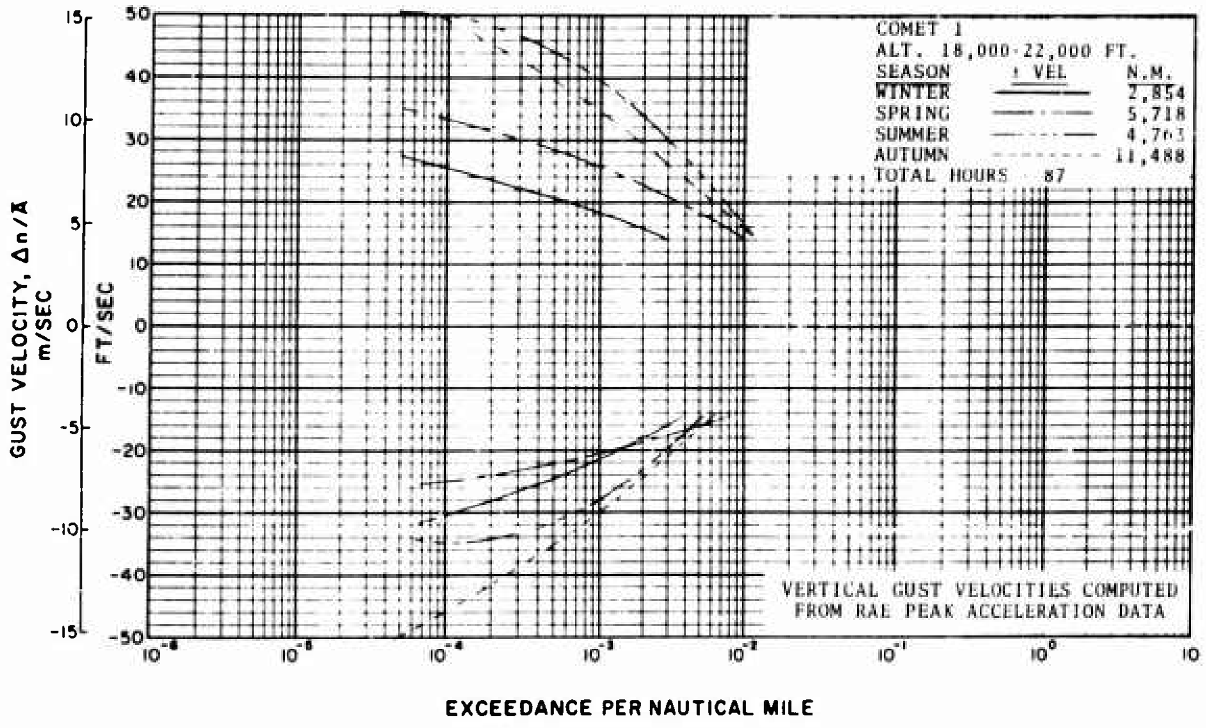
COMET 1
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 422
SPRING 837
SUMMER 781
AUTUMN 1,616
TOTAL HOURS - 19
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

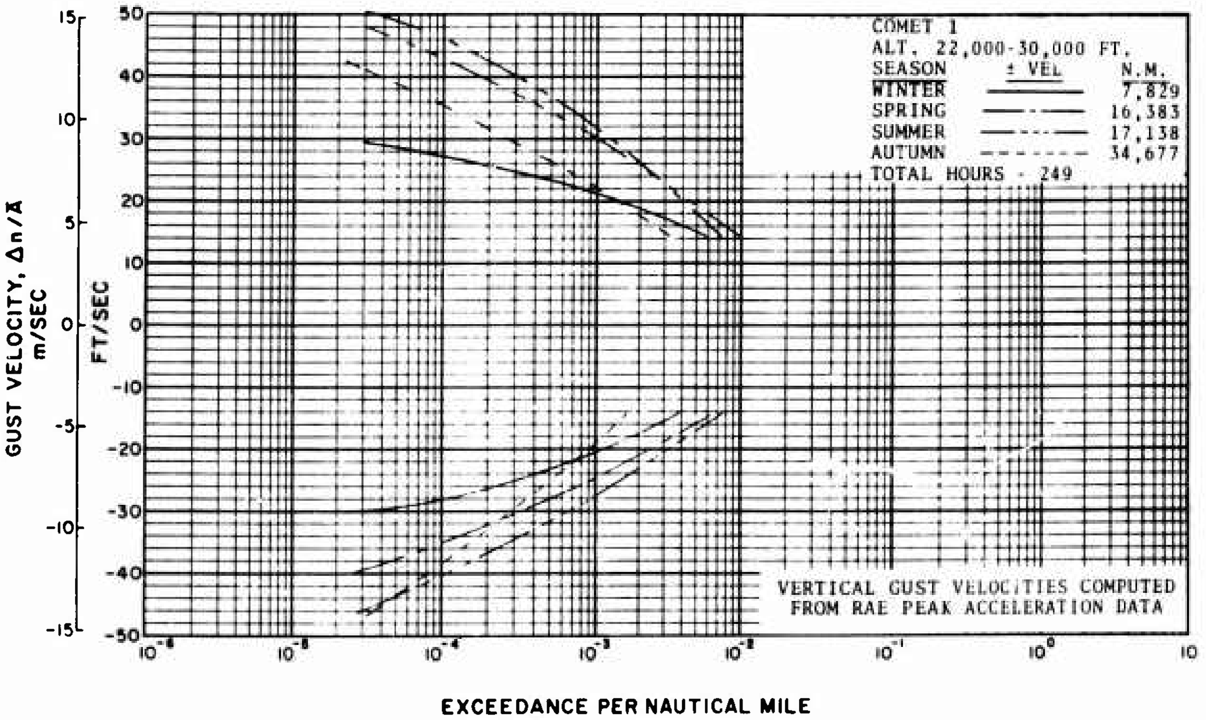

COMET 1
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 590
SPRING 1,845
SUMMER 1,462
AUTUMN 4,111
TOTAL HOURS - 38
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

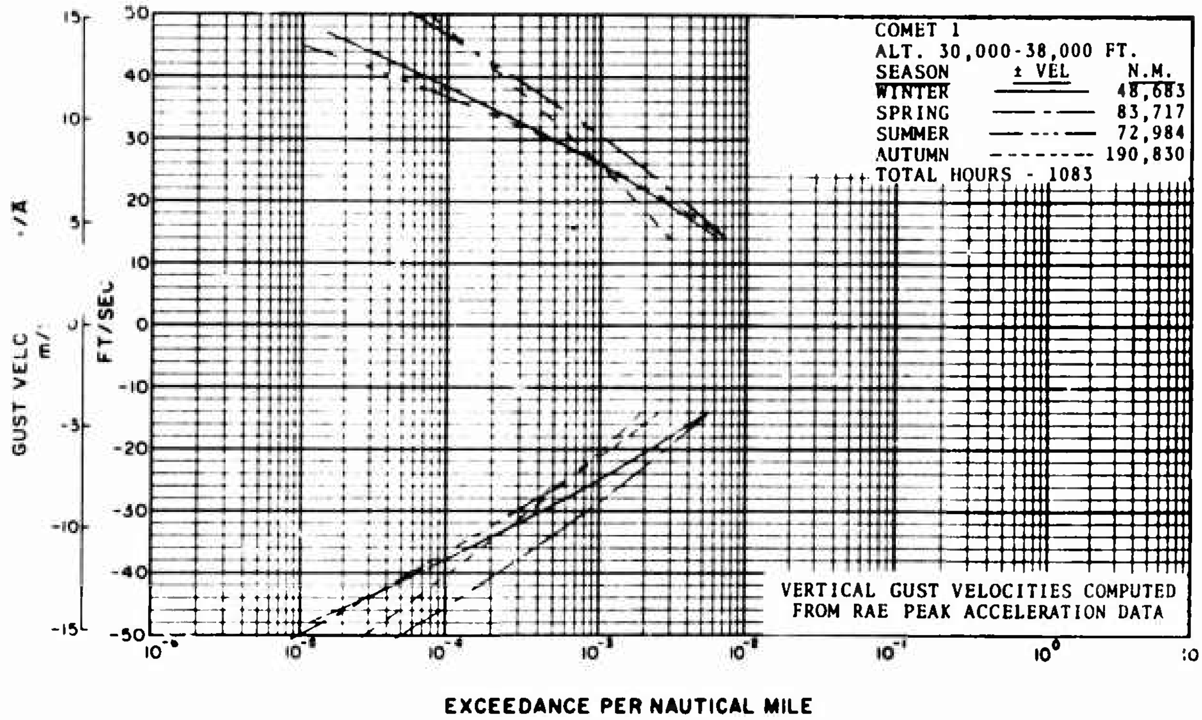

COMET 1
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 1,480
SPRING 2,257
SUMMER 2,095
AUTUMN 4,970
TOTAL HOURS - 47
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

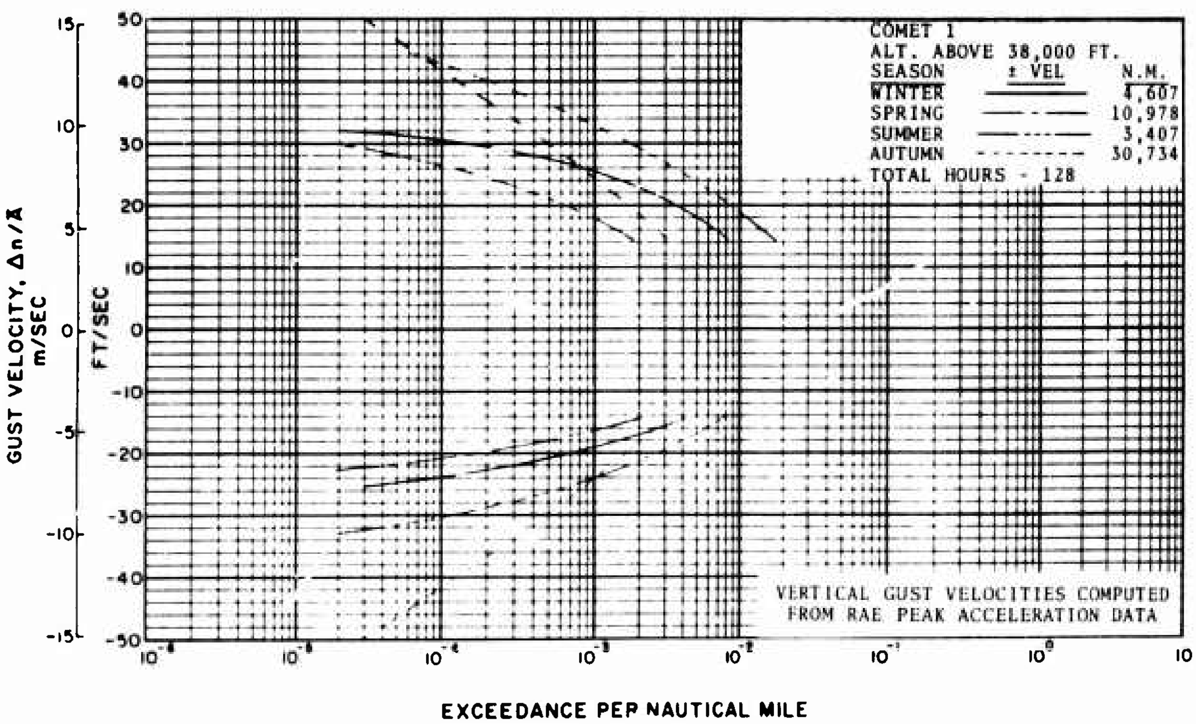

COMET 1
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 1,840
SPRING 4,504
SUMMER 3,693
AUTUMN 9,150
TOTAL HOURS - 74
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

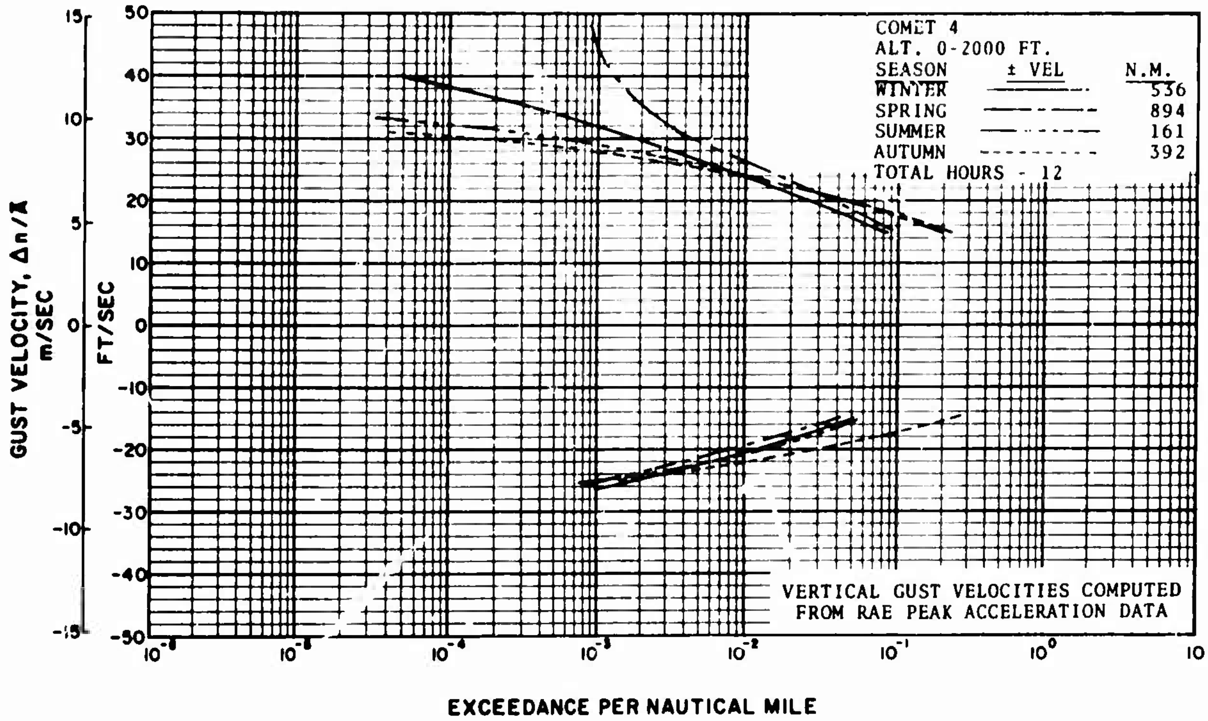

COMET 1
ALT. 14,000-18,000 FT.
SEASON ± VEL N.M.
WINTER 2,535
SPRING 3,750
SUMMER 3,915
AUTUMN 10,145
TOTAL HOURS - 74
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

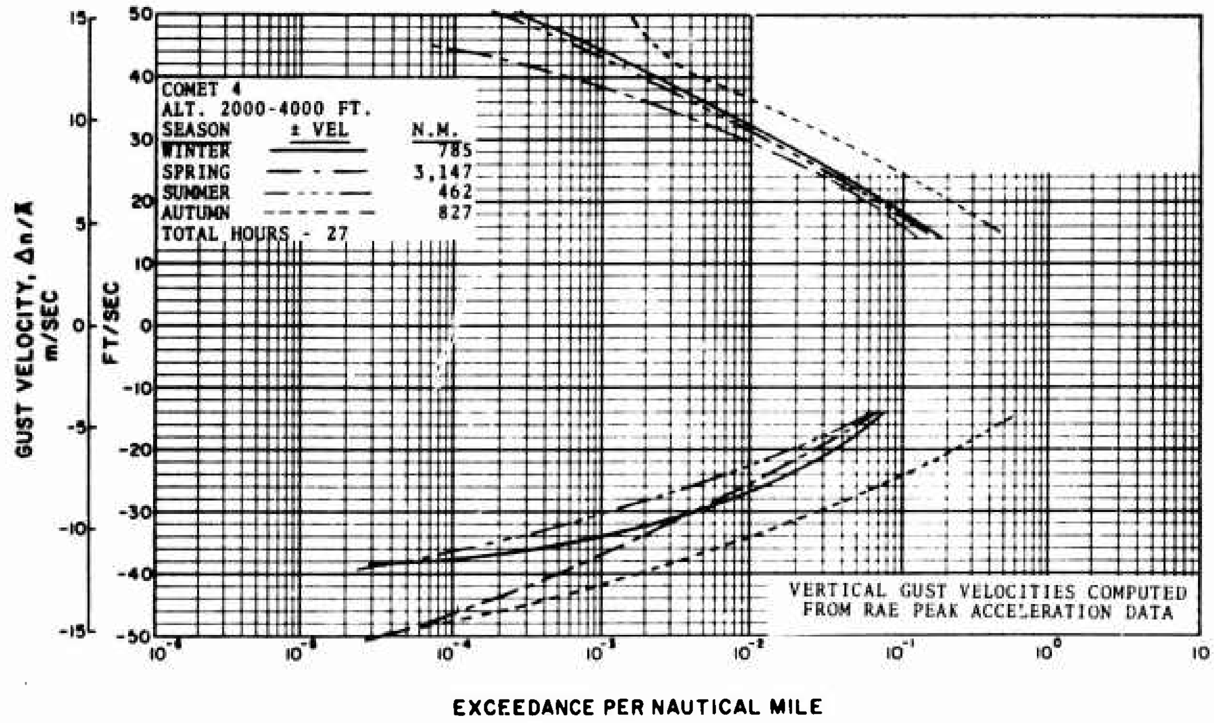

COMET 1
ALT. 18,000-22,000 FT.
SEASON ± VEL N.M.
WINTER 2,854
SPRING 5,718
SUMMER 4,763
AUTUMN 11,488
TOTAL HOURS 87
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

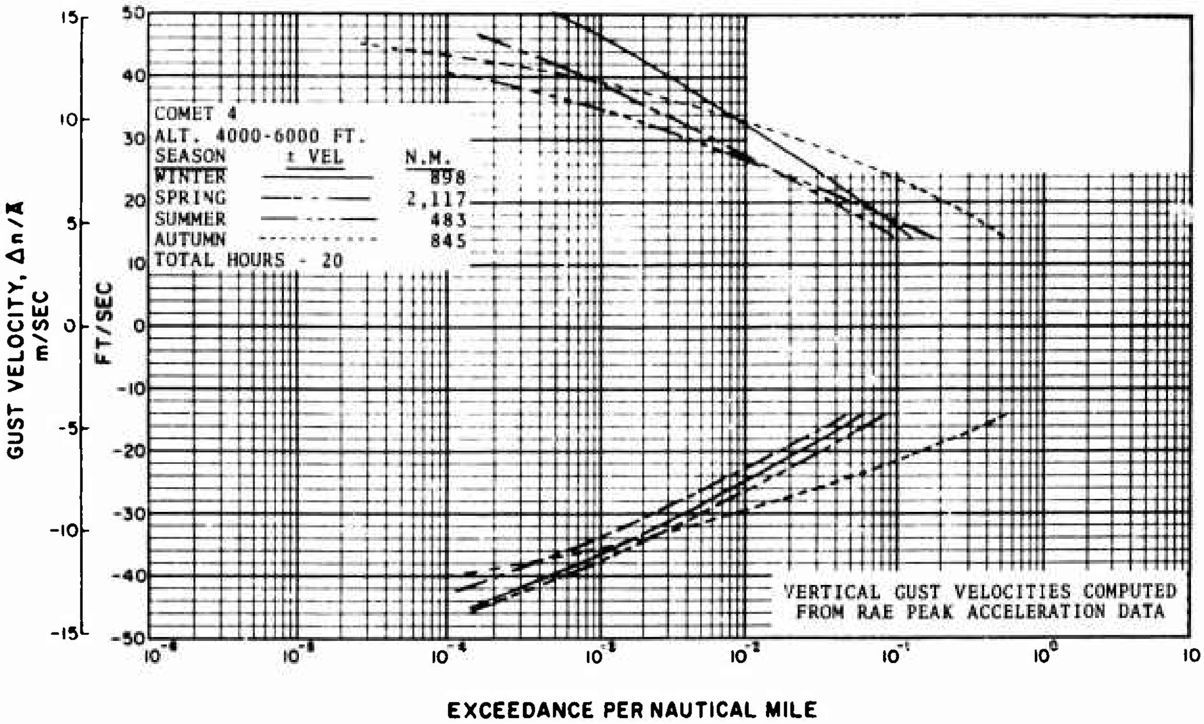

COMET 1
ALT. 22,000-30,000 FT.
SEASON ± VEL N.M.
WINTER 7,829
SPRING 16,383
SUMMER 17,138
AUTUMN 34,677
TOTAL HOURS - 249
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

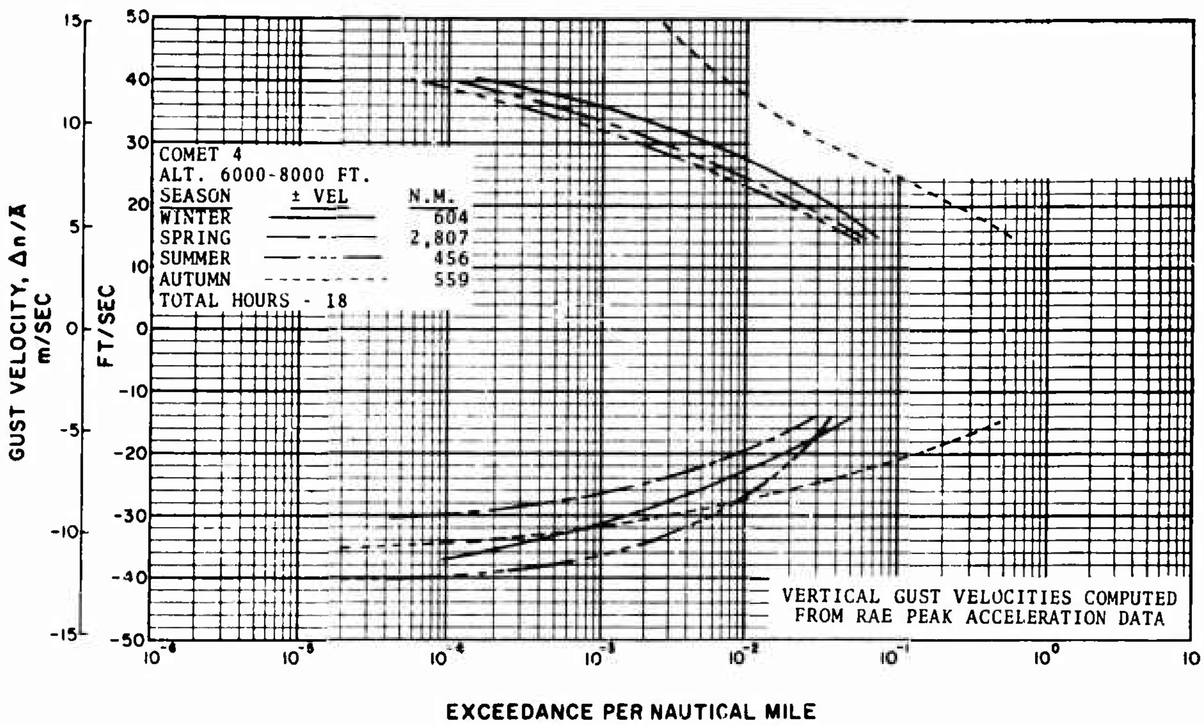

COMET 1
ALT. 30,000-38,000 FT.
SEASON ± VEL N.M.
WINTER 48,683
SPRING 83,717
SUMMER 72,984
AUTUMN 190,830
TOTAL HOURS - 1083
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

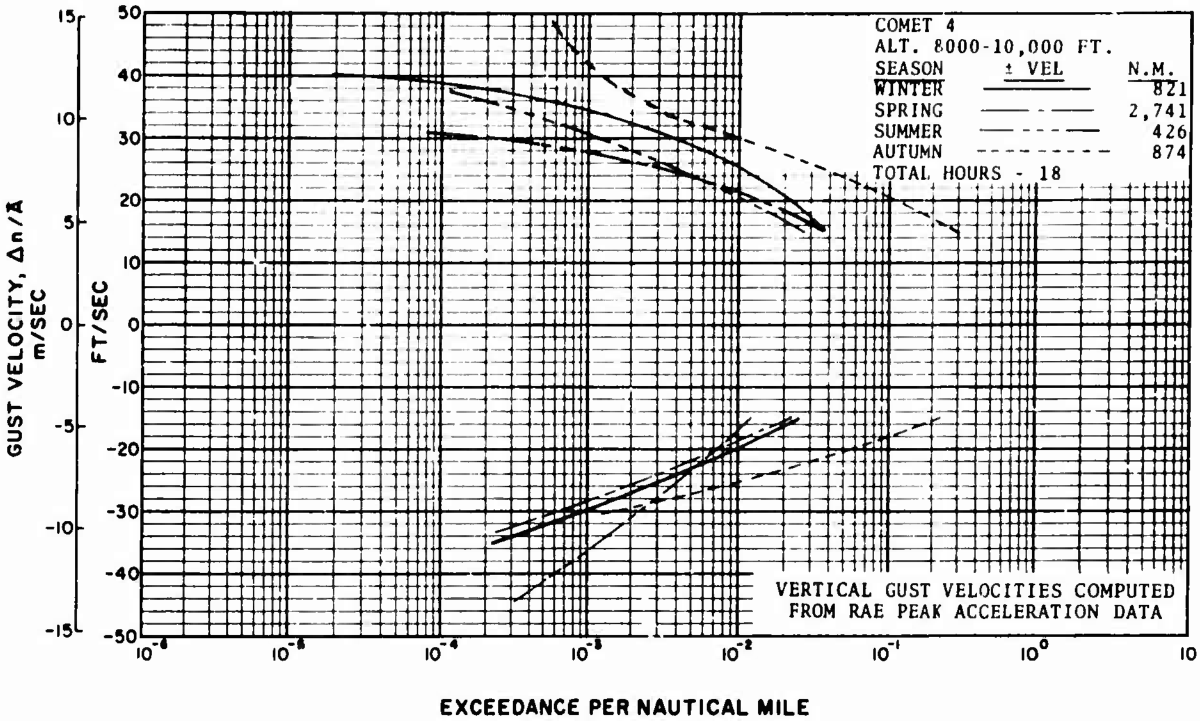

COMET 1
ALT. ABOVE 38,000 FT.
SEASON ± VEL N.M.
WINTER 4,607
SPRING 10,978
SUMMER 3,407
AUTUMN 30,734
TOTAL HOURS - 128
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


COMET 4
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 536
SPRING 894
SUMMER 161
AUTUMN 392
TOTAL HOURS - 12
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

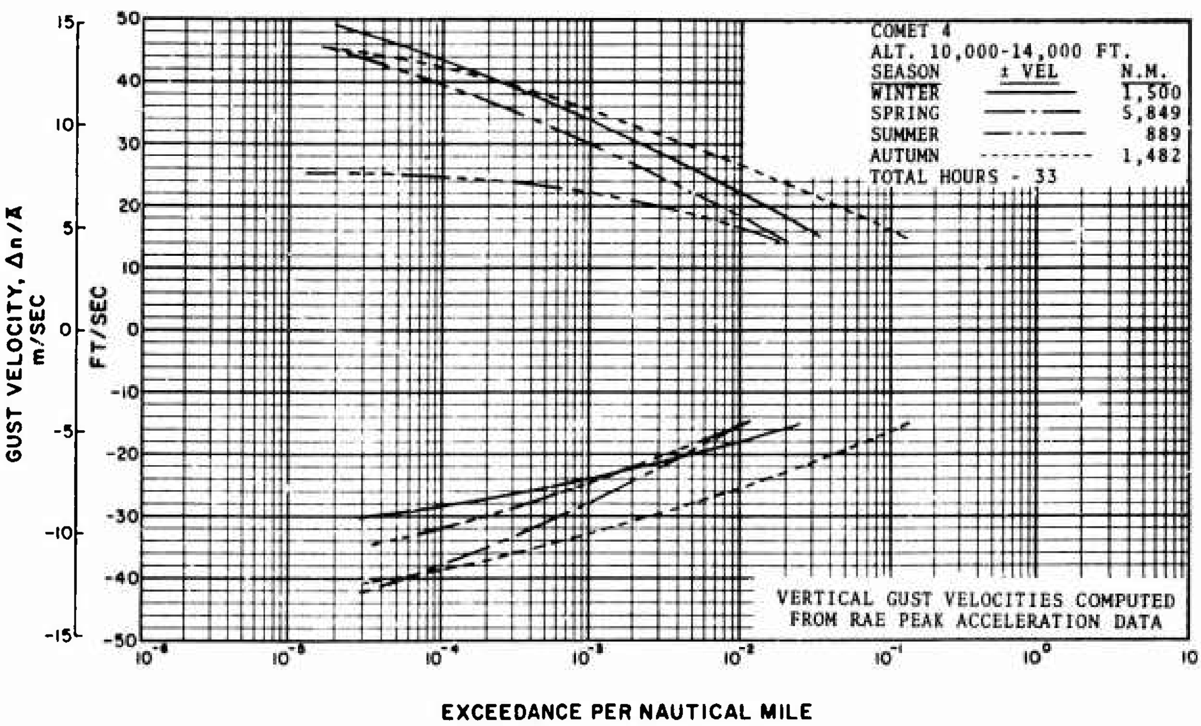

COMET 4
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 785
SPRING 3,147
SUMMER 462
AUTUMN 827
TOTAL HOURS - 27
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


COMET 4
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 898
SPRING 2,117
SUMMER 483
AUTUMN 845
TOTAL HOURS - 20
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

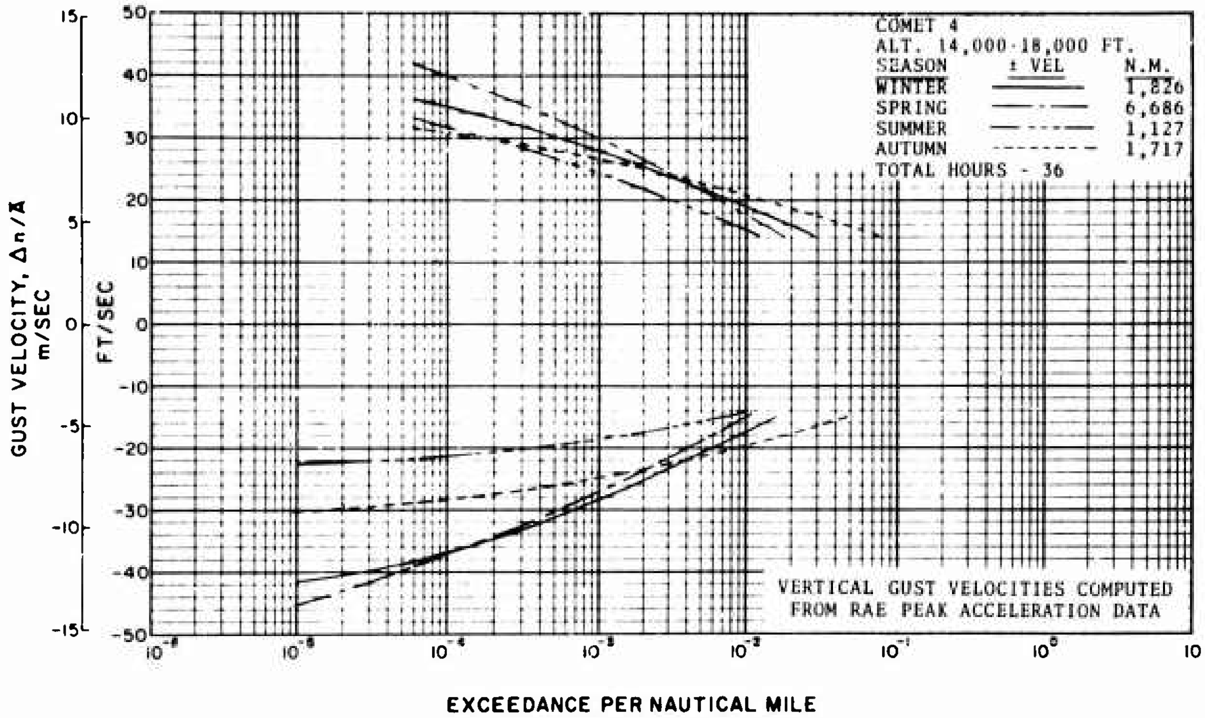

COMET 4
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 604
SPRING 2,807
SUMMER 456
AUTUMN 559
TOTAL HOURS - 18
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

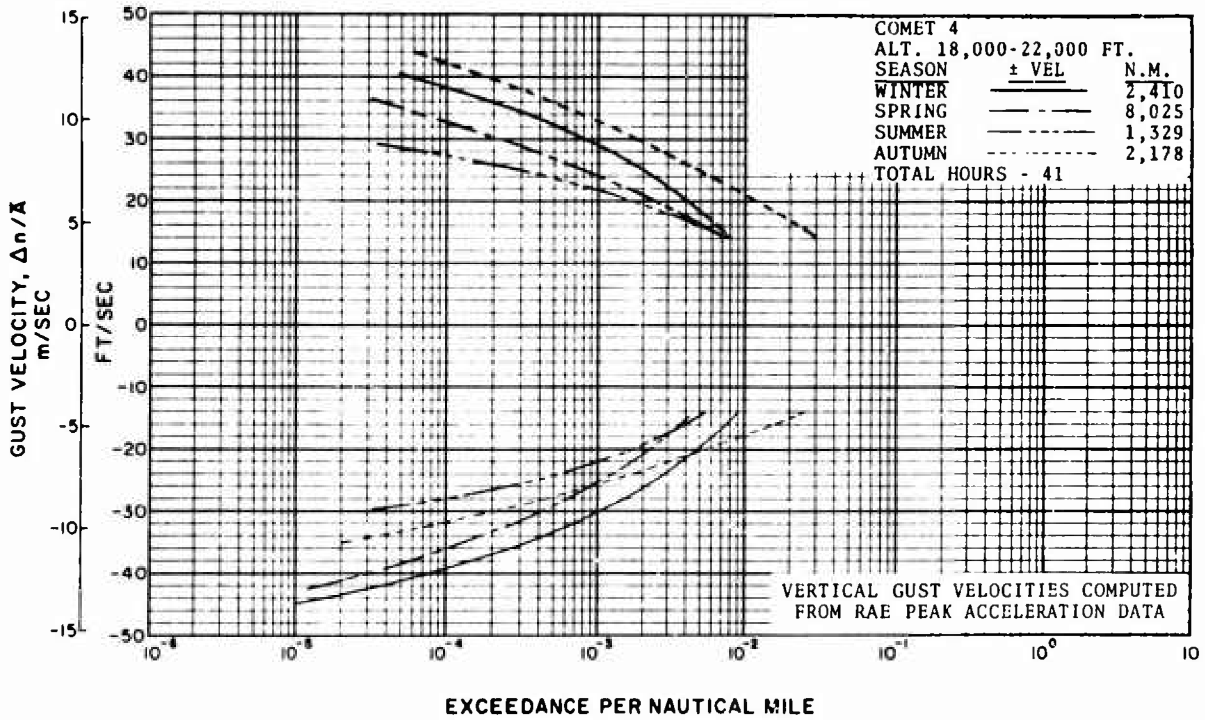


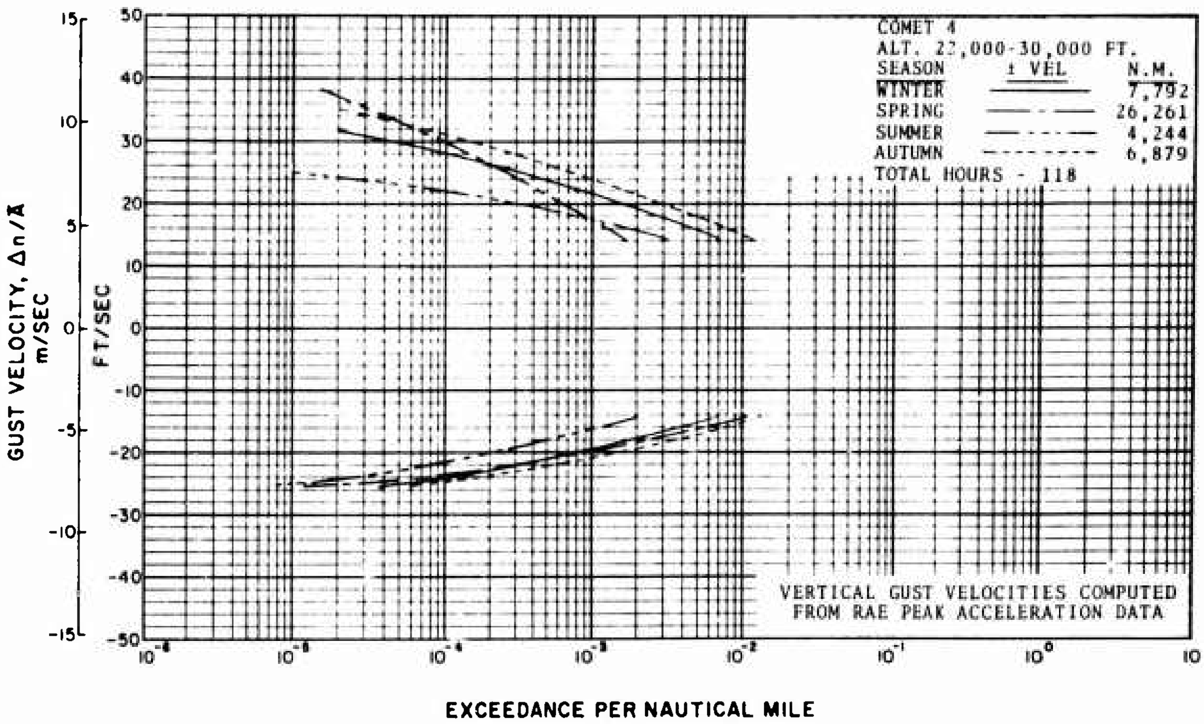
COMET 4
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 821
SPRING 2,741
SUMMER 426
AUTUMN 874
TOTAL HOURS - 18
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

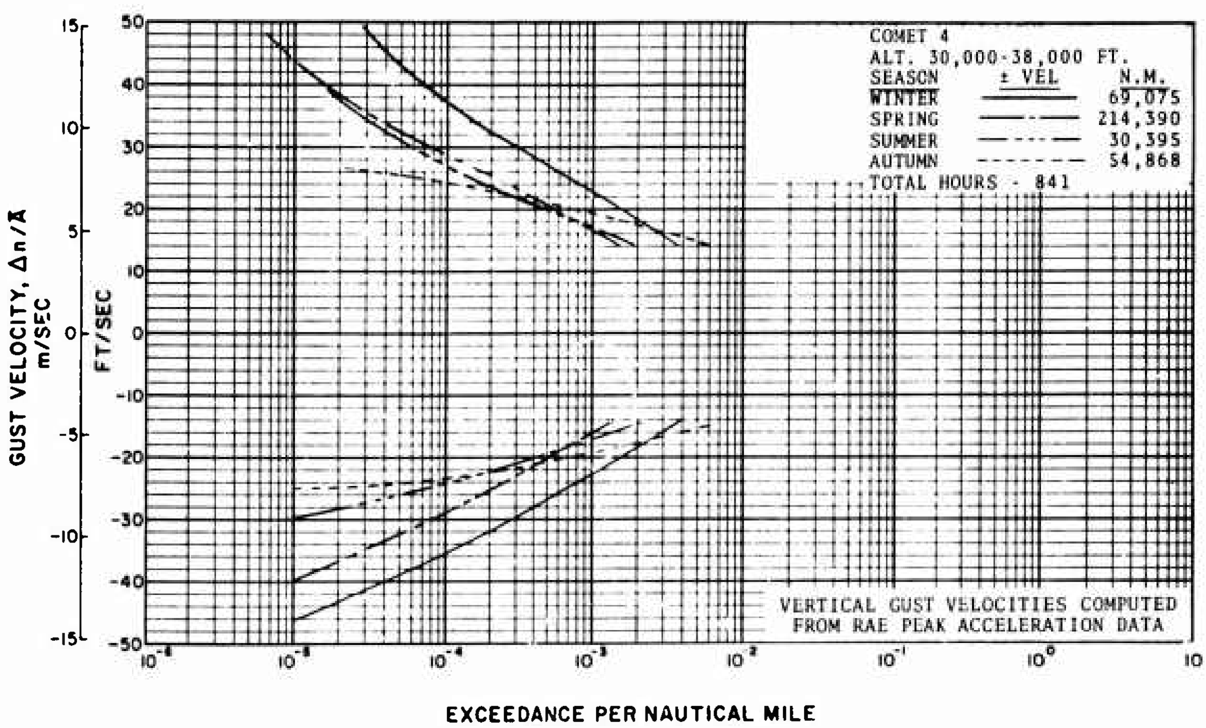


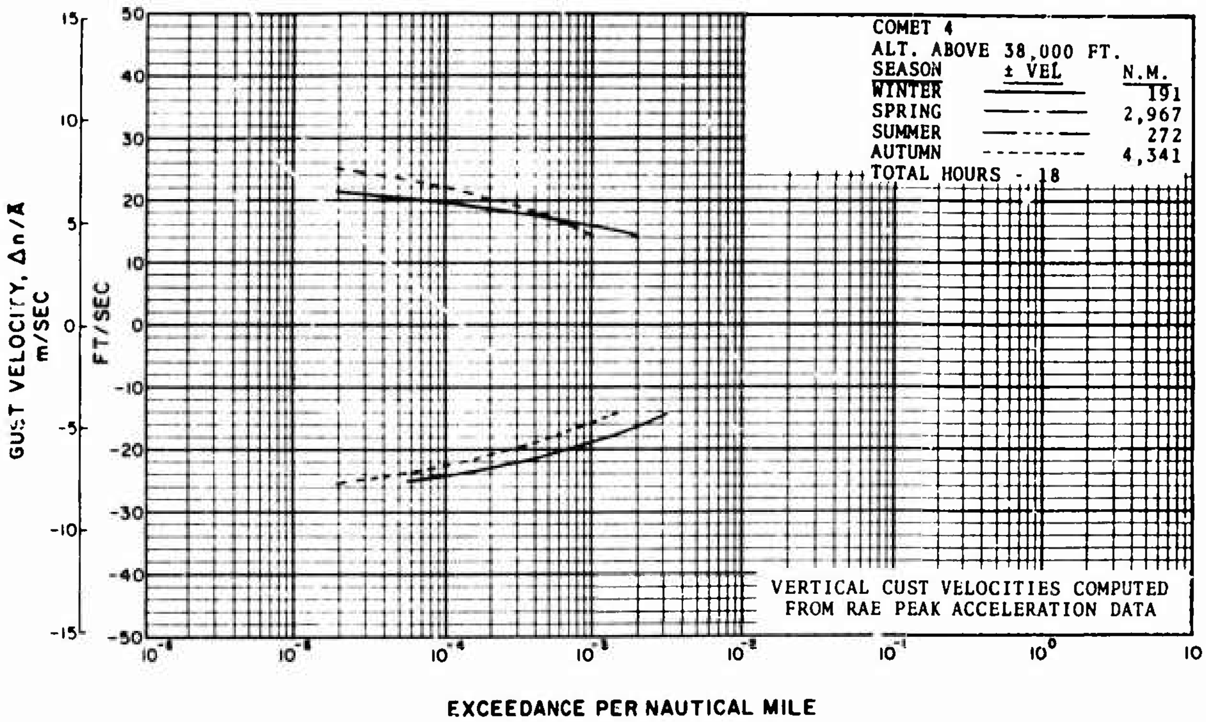
COMET 4
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 1,500
SPRING 5,849
SUMMER 889
AUTUMN 1,482
TOTAL HOURS - 33
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


COMET 4
ALT. 14,000-18,000 FT.
SEASON ± VEL N.M.
WINTER 1,826
SPRING 6,686
SUMMER 1,127
AUTUMN 1,717
TOTAL HOURS - 36
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

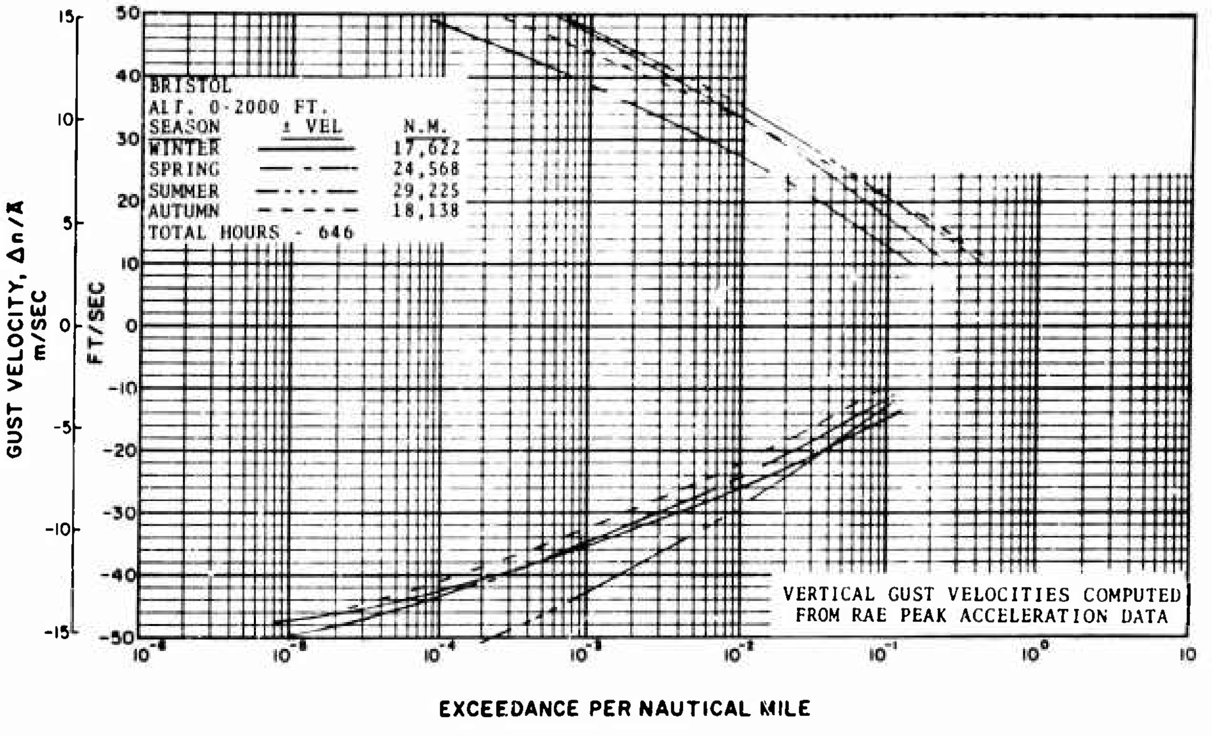

COMET 4
ALT. 18,000-22,000 FT.
SEASON ± VEL N.M.
WINTER 2,410
SPRING 8,025
SUMMER 1,329
AUTUMN 2,178
TOTAL HOURS - 41
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


COMET 4
ALT. 22,000-30,000 FT.
SEASON ± VEL N.M.
WINTER 7,792
SPRING 26,261
SUMMER 4,244
AUTUMN 6,879
TOTAL HOURS - 118
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

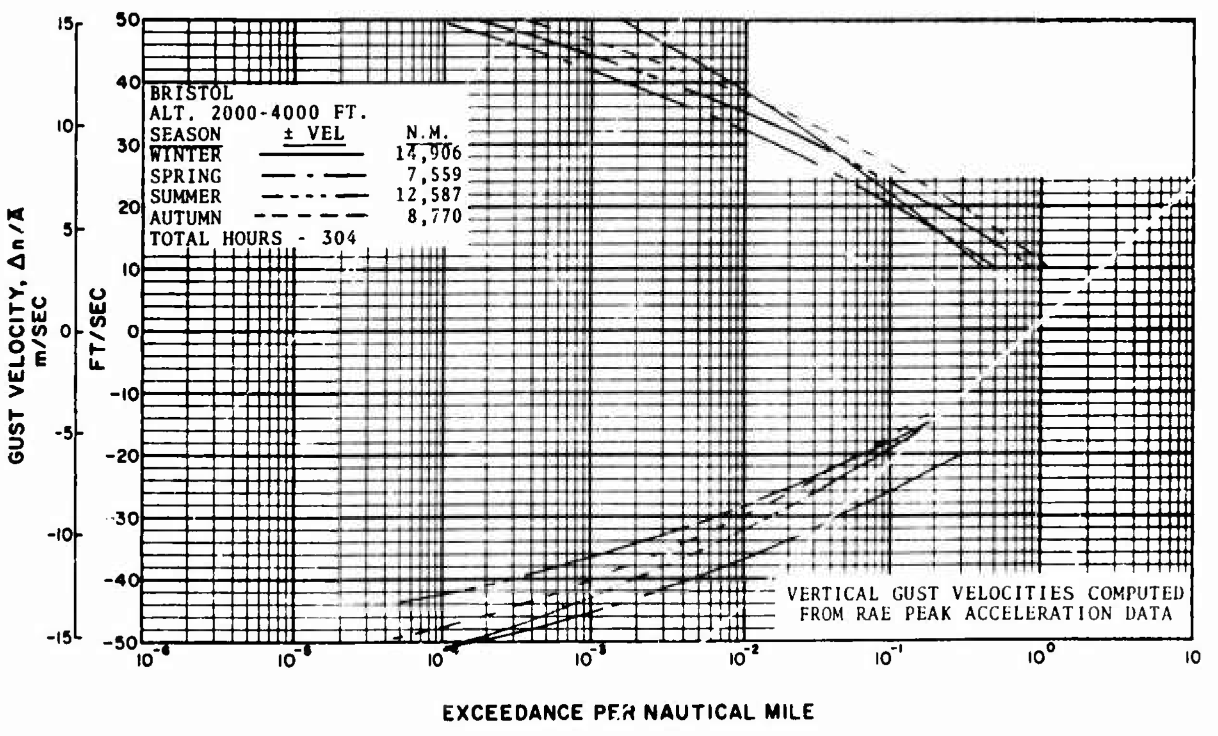

COMET 4
ALT. 30,000-38,000 FT.
SEASON ± VEL N.M.
WINTER 69,075
SPRING 214,390
SUMMER 30,395
AUTUMN 54,868
TOTAL HOURS - 841
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE



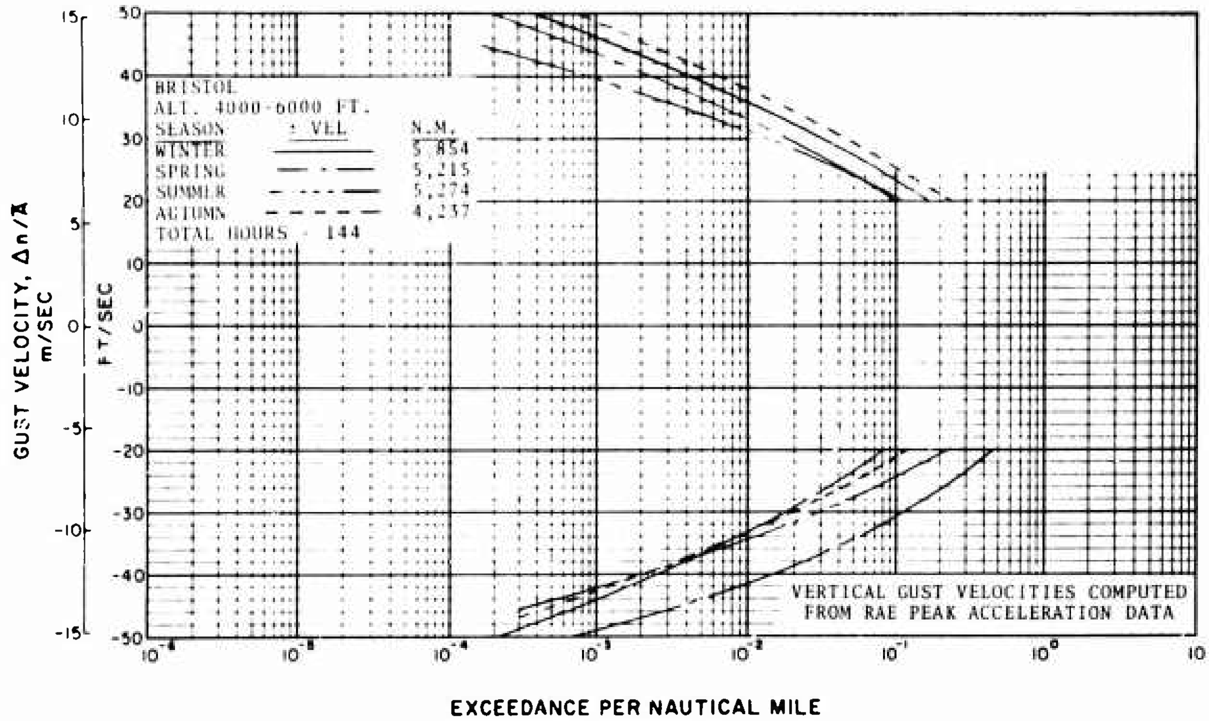
COMET 4
ALT. ABOVE 38,000 FT.
SEASON ± VEL N.M.
WINTER 191
SPRING 2,967
SUMMER 272
AUTUMN 4,341
TOTAL HOURS - 18
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE



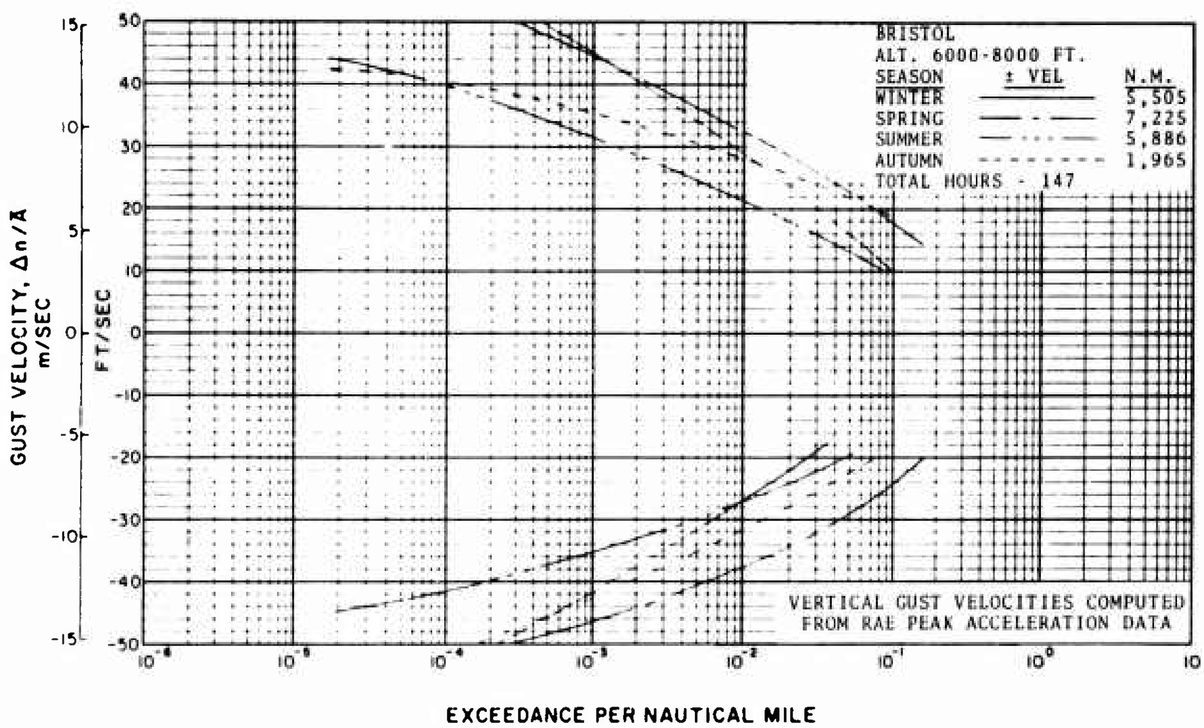
BRISTOL
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 17,622
SPRING 24,568
SUMMER 29,225
AUTUMN 18,138
TOTAL HOURS - 646
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE



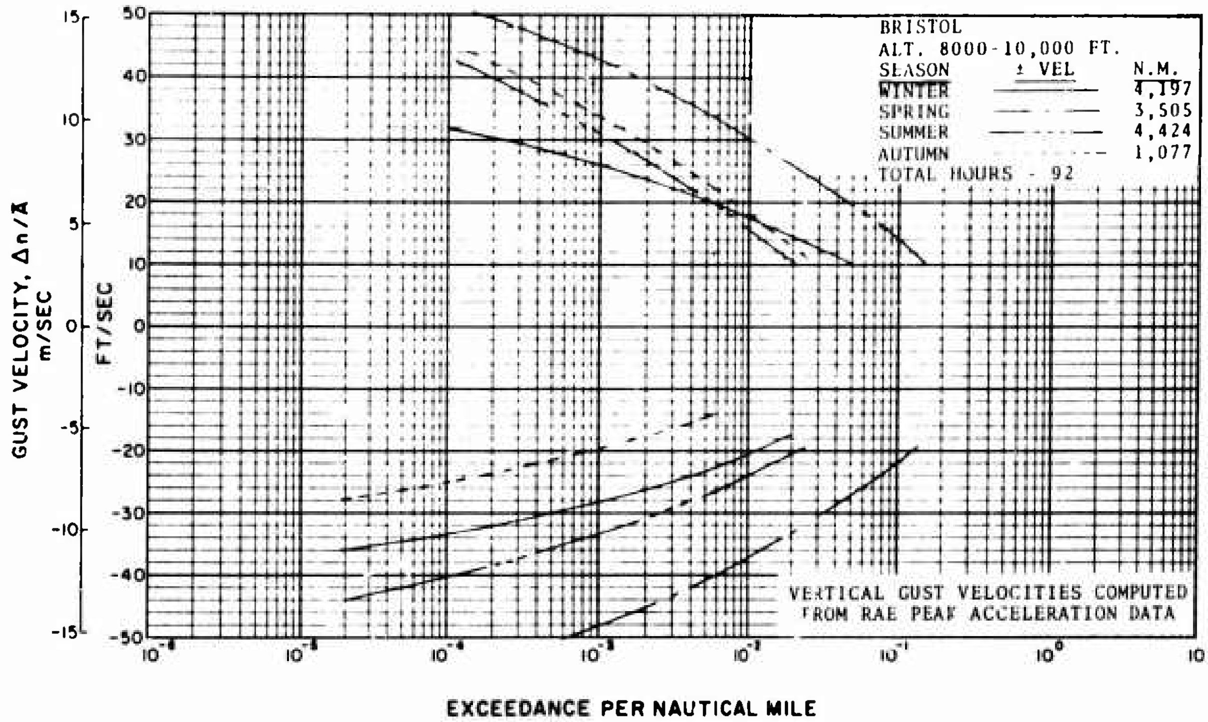
BRISTOL
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 14,906
SPRING 7,559
SUMMER 12,587
AUTUMN 8,770
TOTAL HOURS - 304
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

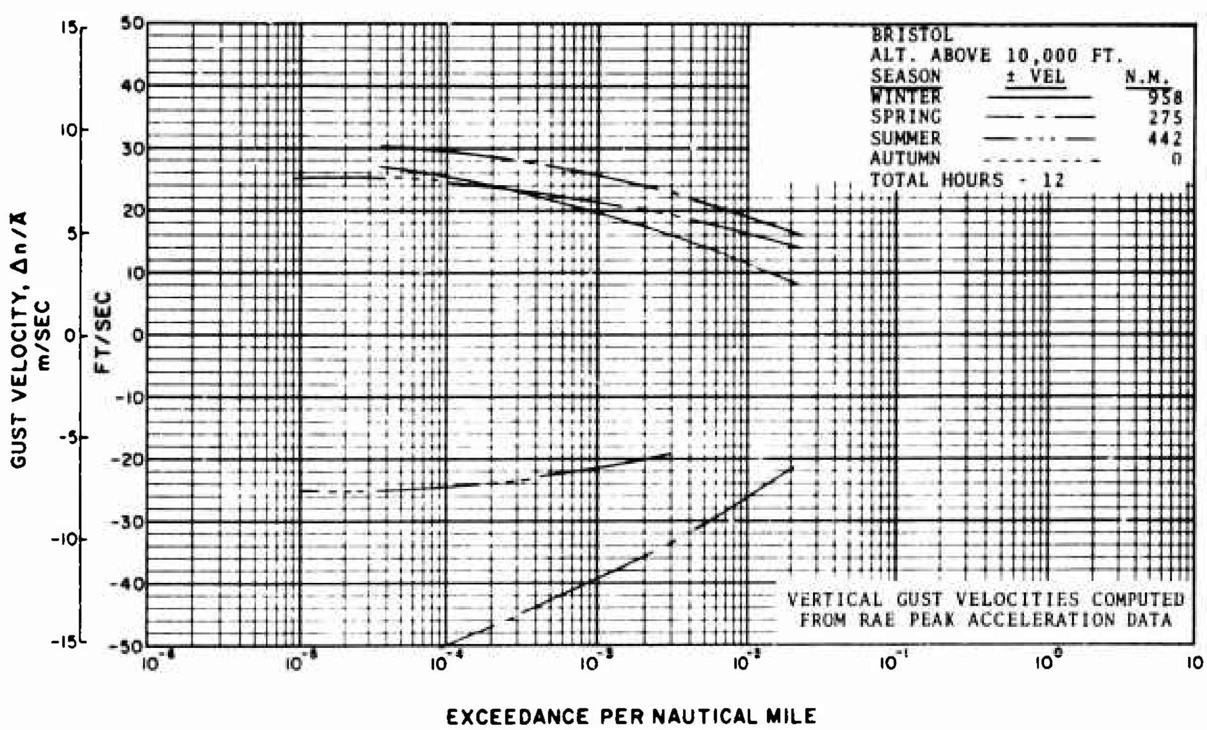


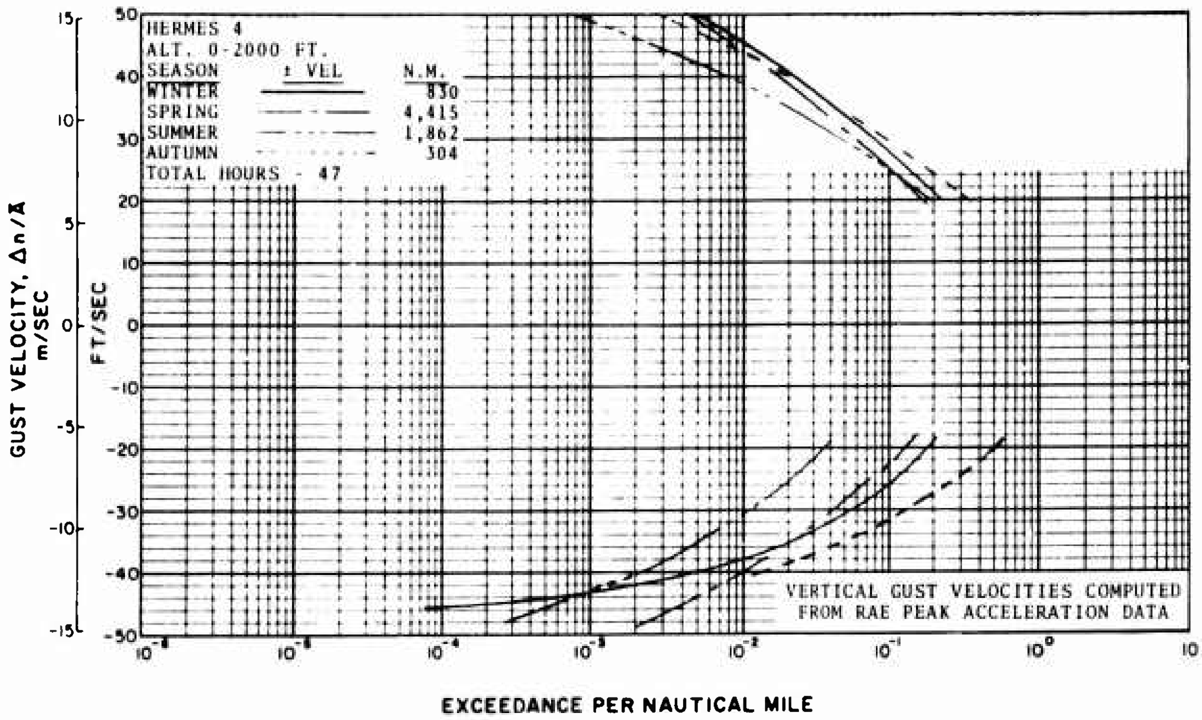
BRISTOL
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 5,854
SPRING 5,215
SUMMER 5,274
AUTUMN 4,237
TOTAL HOURS - 144
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

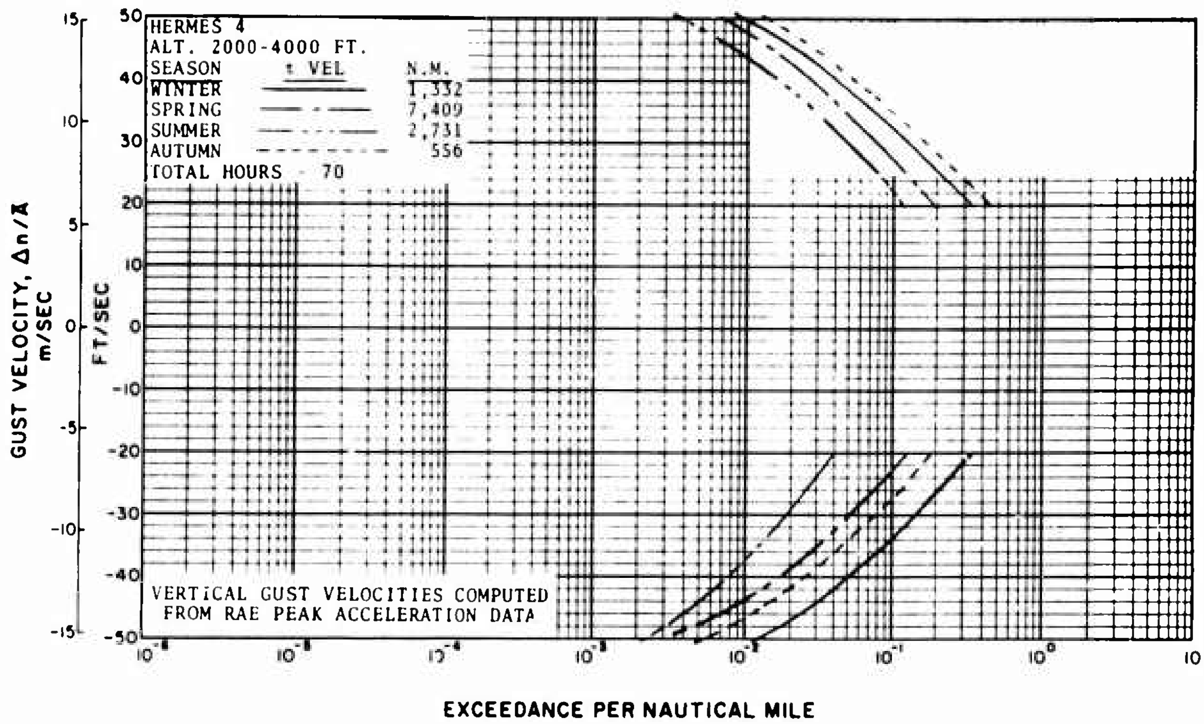


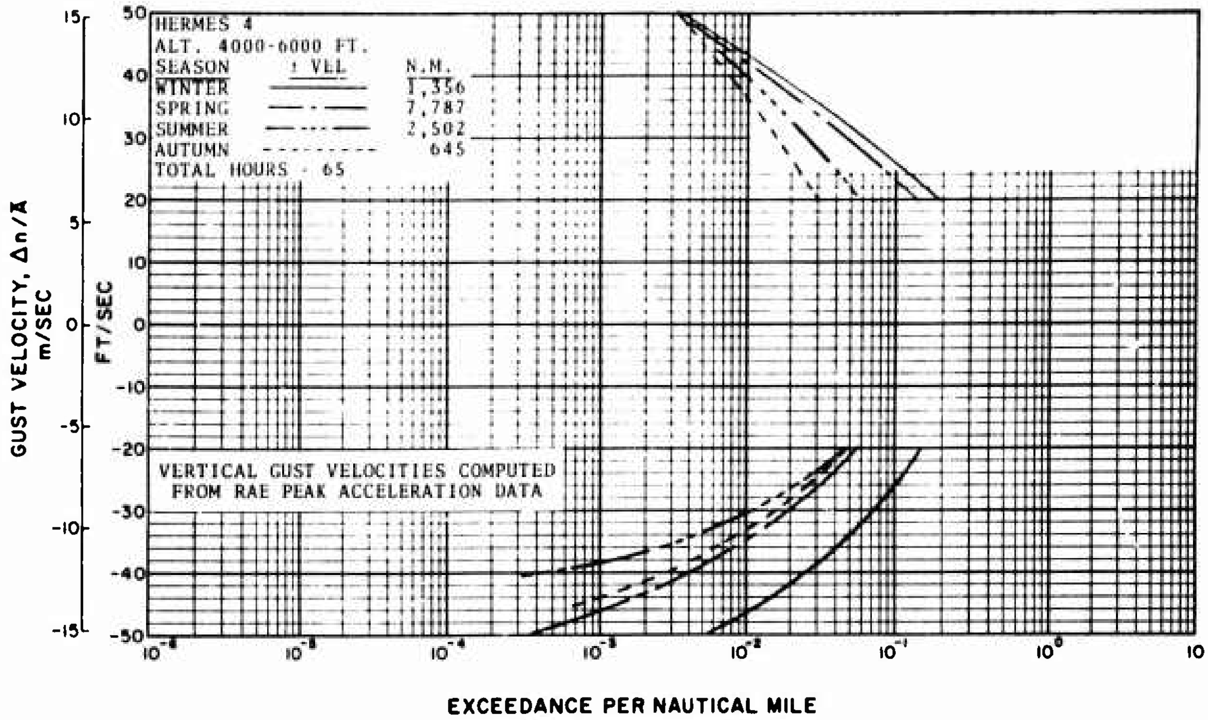
BRISTOL
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 5,505
SPRING 7,225
SUMMER 5,886
AUTUMN 1,965
TOTAL HOURS - 147
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

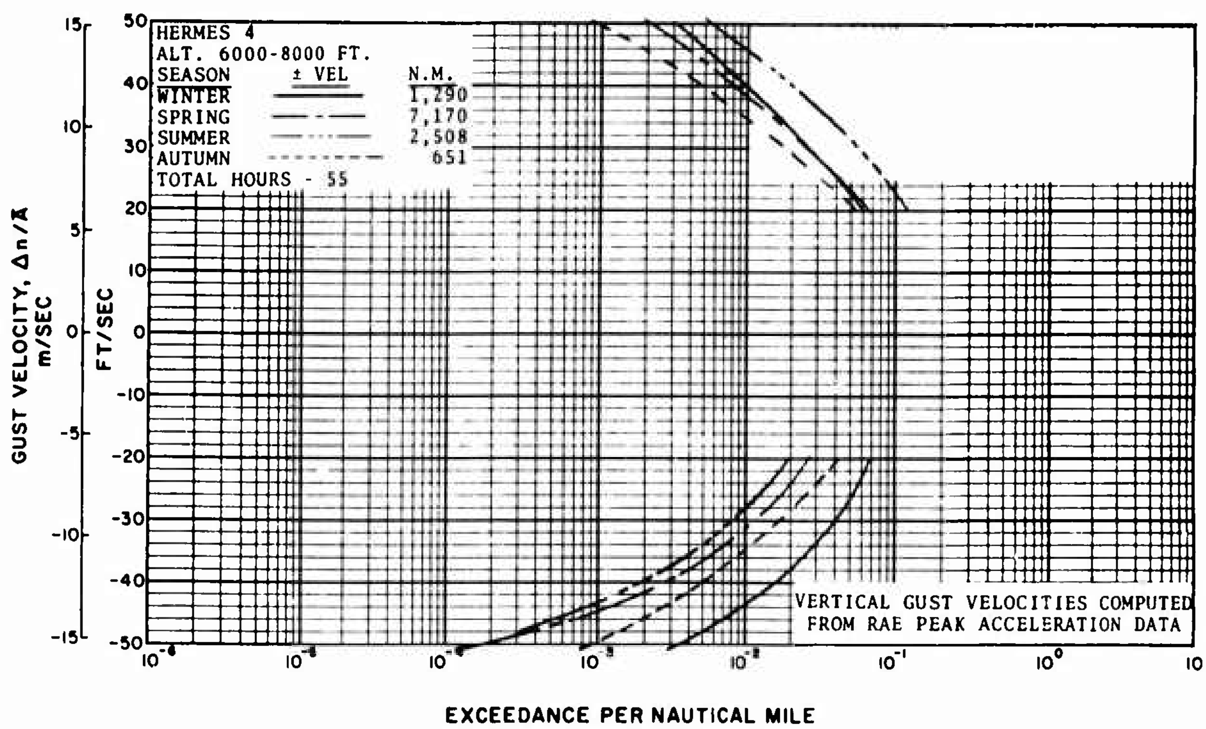

BRISTOL
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 4,197
SPRING 3,505
SUMMER 4,424
AUTUMN 1,077
TOTAL HOURS - 92
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

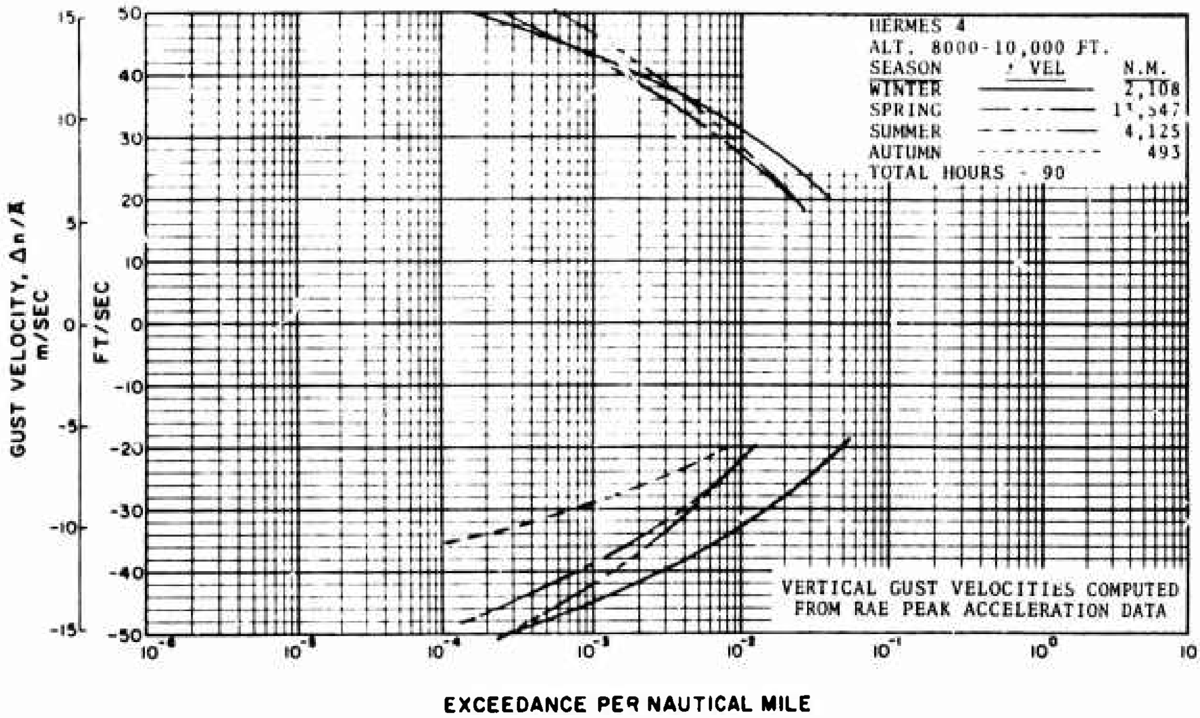

BRISTOL
ALT. ABOVE 10,000 FT.
SEASON ± VEL N.M.
WINTER 958
SPRING 275
SUMMER 442
AUTUMN 0
TOTAL HOURS - 12
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

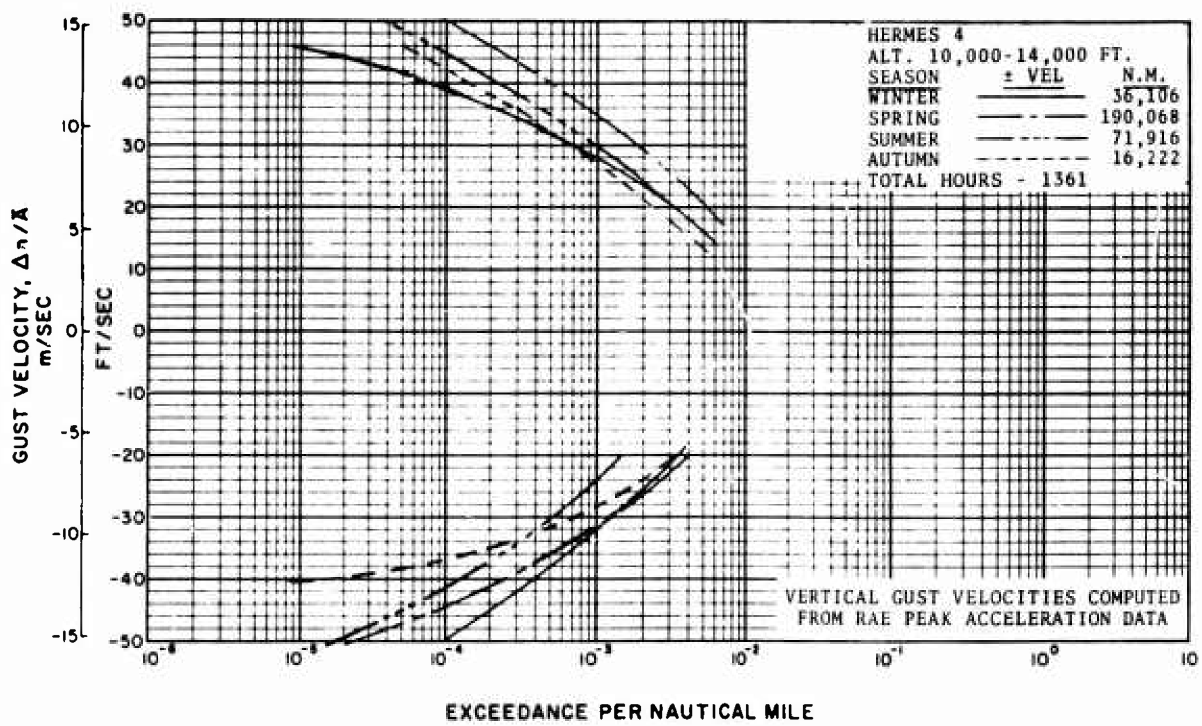

HERMES 4
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 830
SPRING 4,415
SUMMER 1,862
AUTUMN 304
TOTAL HOURS - 47
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

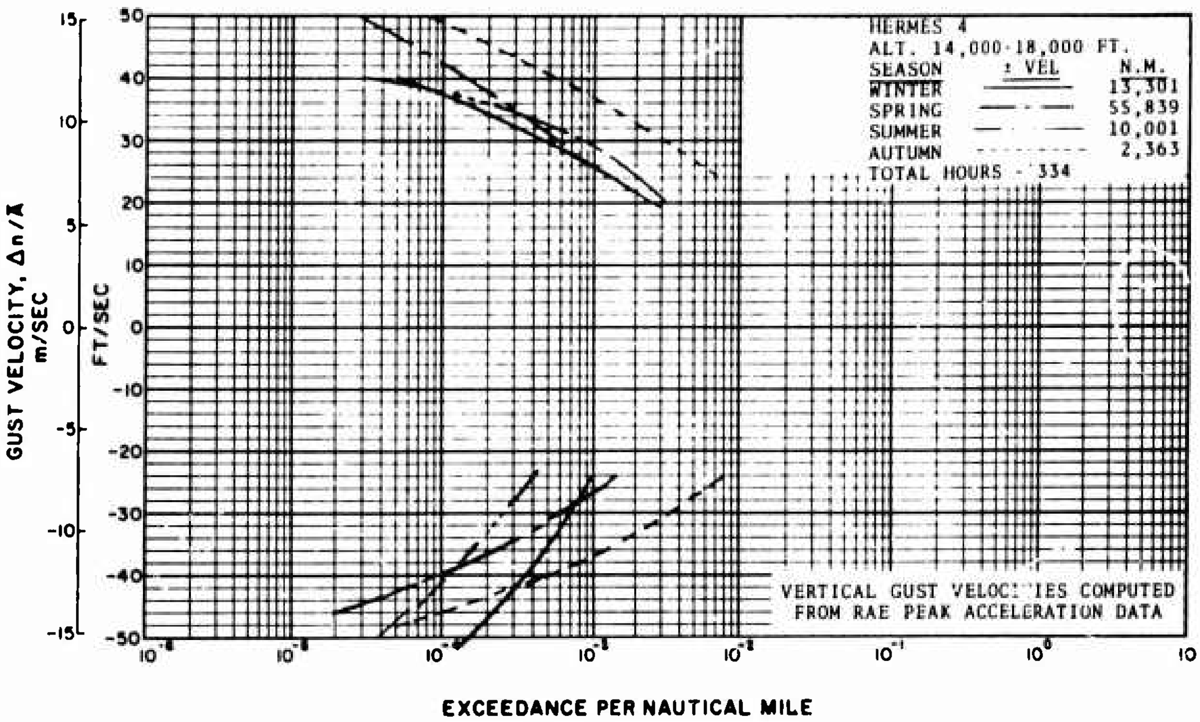

HERMES 4
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 1,332
SPRING 7,409
SUMMER 2,731
AUTUMN 556
TOTAL HOURS - 70
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

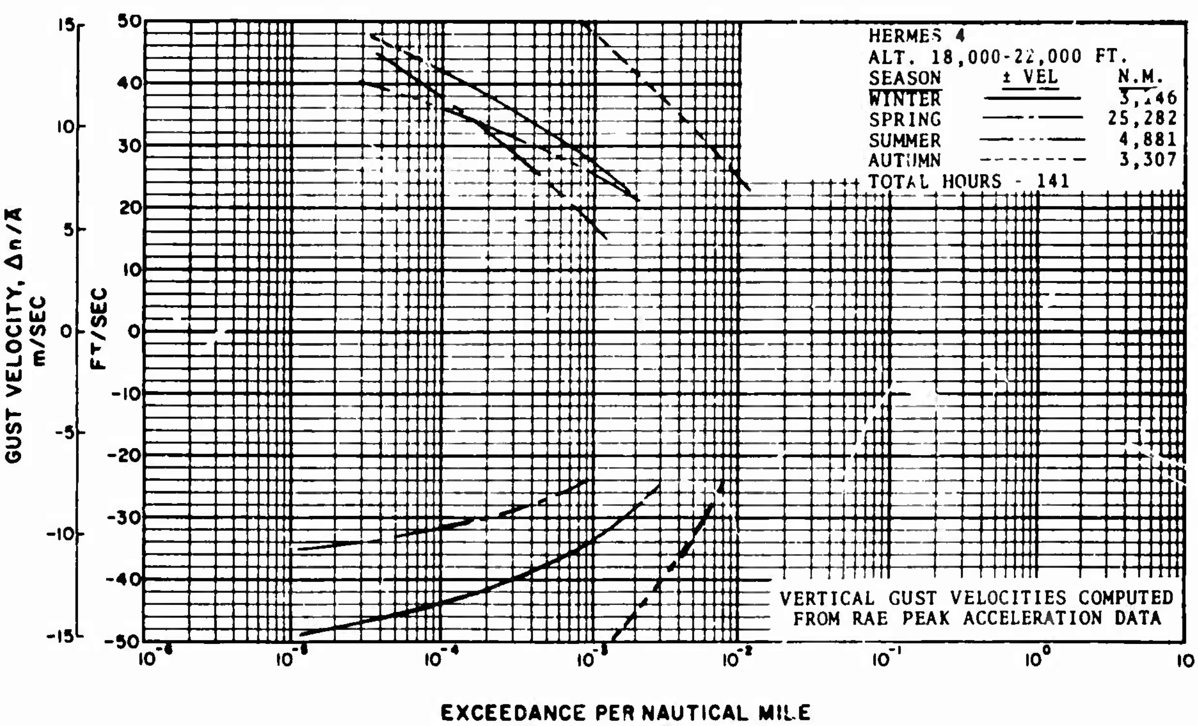

HERMES 4
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 1,356
SPRING 7,787
SUMMER 2,502
AUTUMN 645
TOTAL HOURS - 65
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

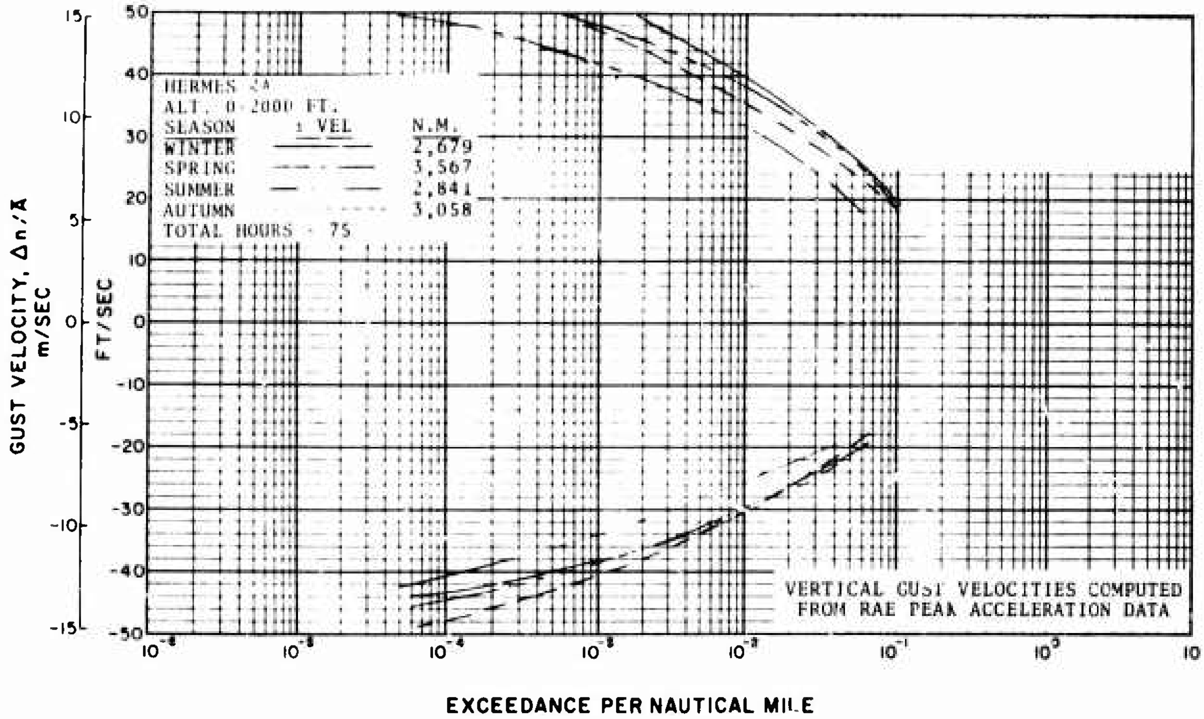

HERMES 4
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 1,290
SPRING 7,170
SUMMER 2,508
AUTUMN 651
TOTAL HOURS - 55
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

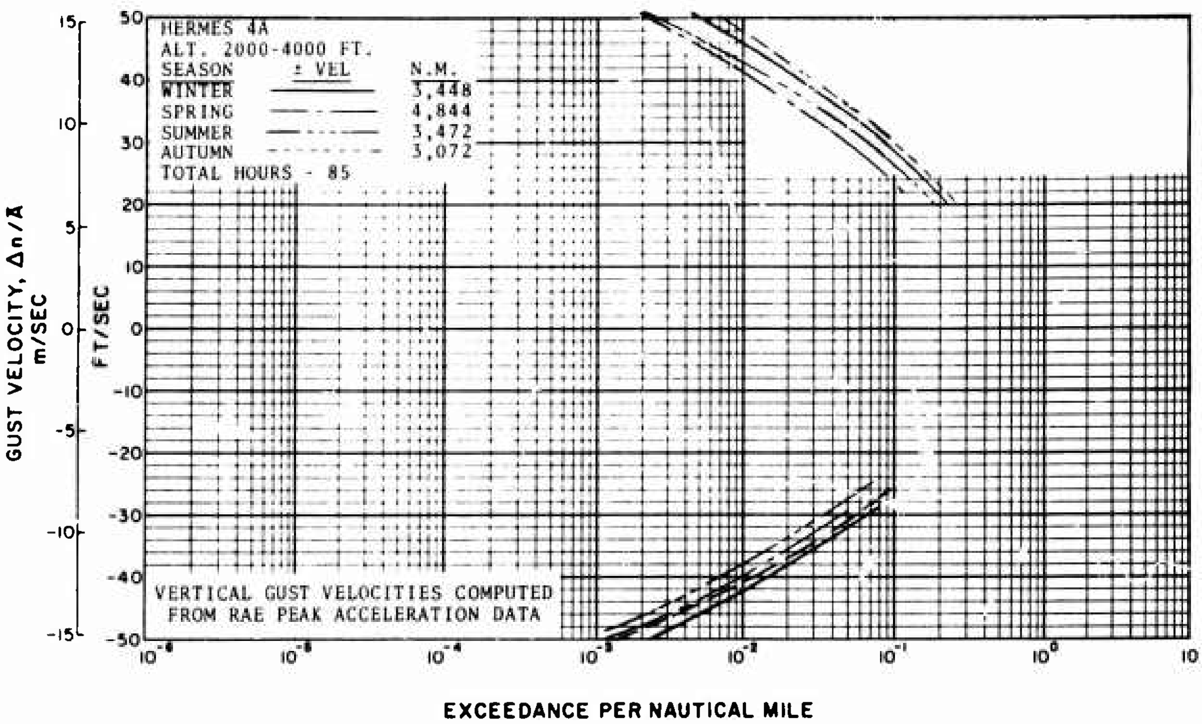

HERMES 4
ALT. 8000-10,000 FT.
SEASON
VEL
N.M.
WINTER
2,108
SPRING
SUMMER
4,125
AUTUMN
493
TOTAL HOURS - 90
VERTICAL GUST VELOCITIES COMPUTED
FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā
m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE
15
10
5
0
-5
-10
-15
50
40
30
20
10
0
-10
-20
-30
-40
-50
10

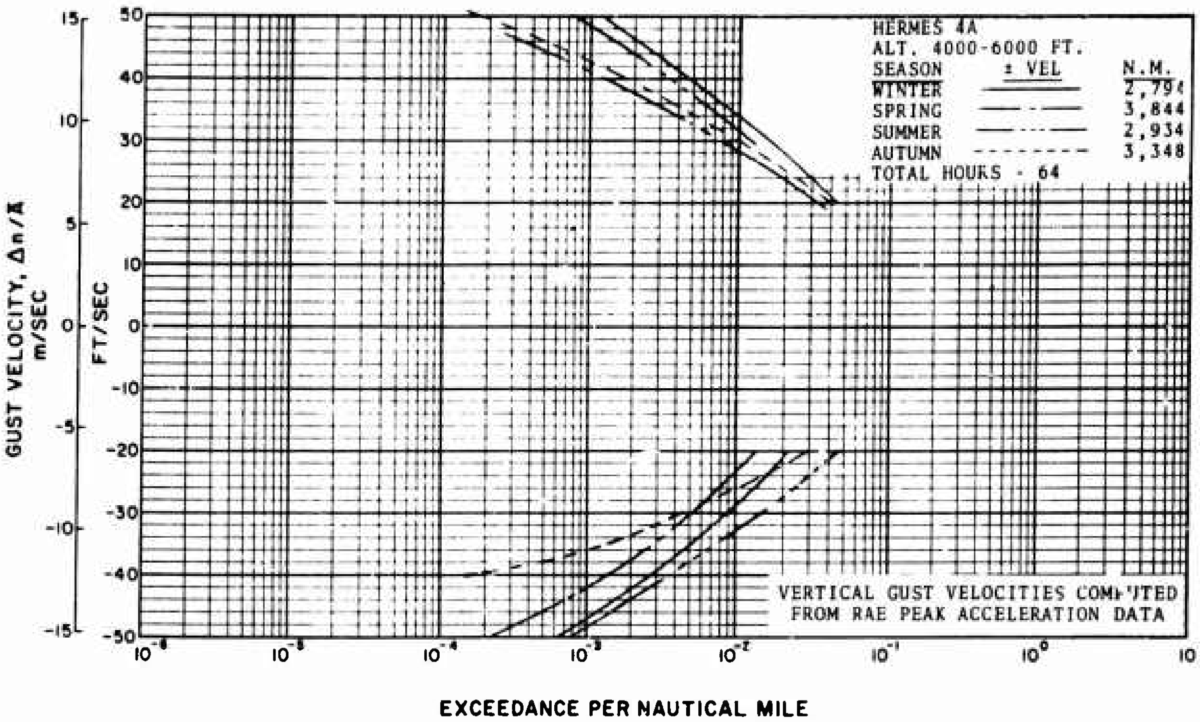

HERMES 4
ALT. 10,000-14,000 FT.
SEASON
± VEL
N.M.
WINTER
36,106
SPRING
190,068
SUMMER
71,916
AUTUMN
16,222
TOTAL HOURS - 1361
VERTICAL GUST VELOCITIES COMPUTED
FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā
m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE
15
10
5
0
-5
-10
-15
50
40
30
20
10
0
-10
-20
-30
-40
-50
10

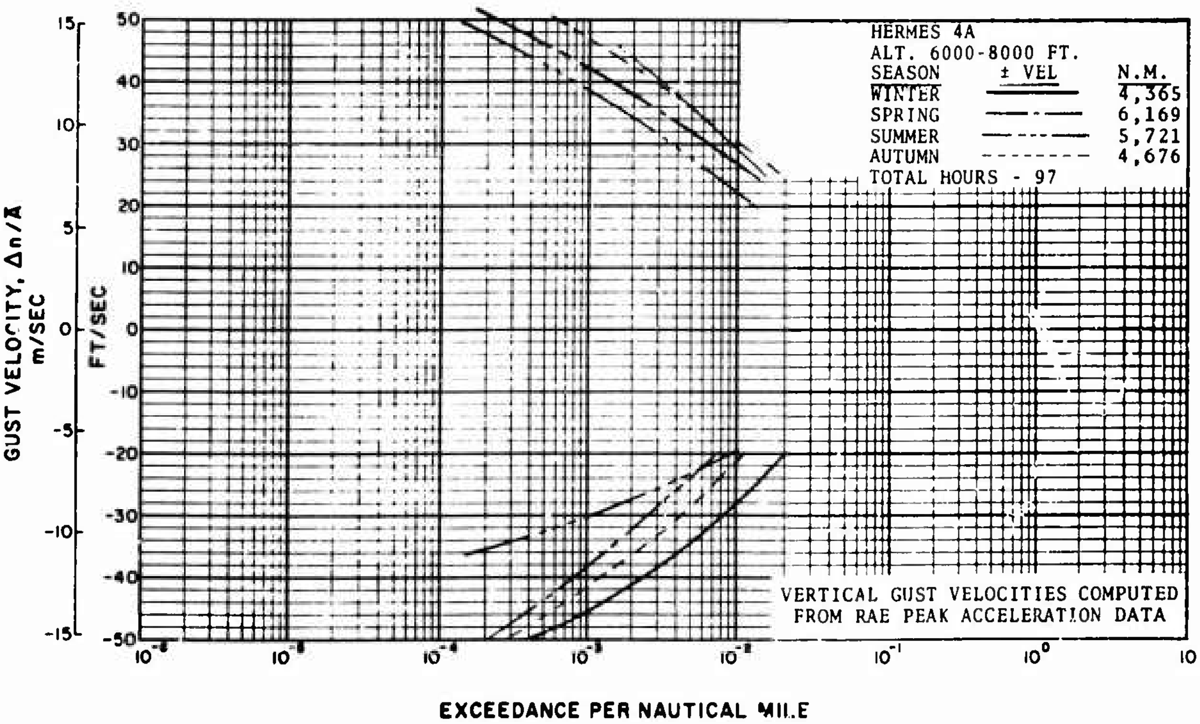

HERMES 4
ALT. 14,000-18,000 FT.
SEASON ± VEL N.M.
WINTER 13,301
SPRING 55,839
SUMMER 10,001
AUTUMN 2,363
TOTAL HOURS - 334
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

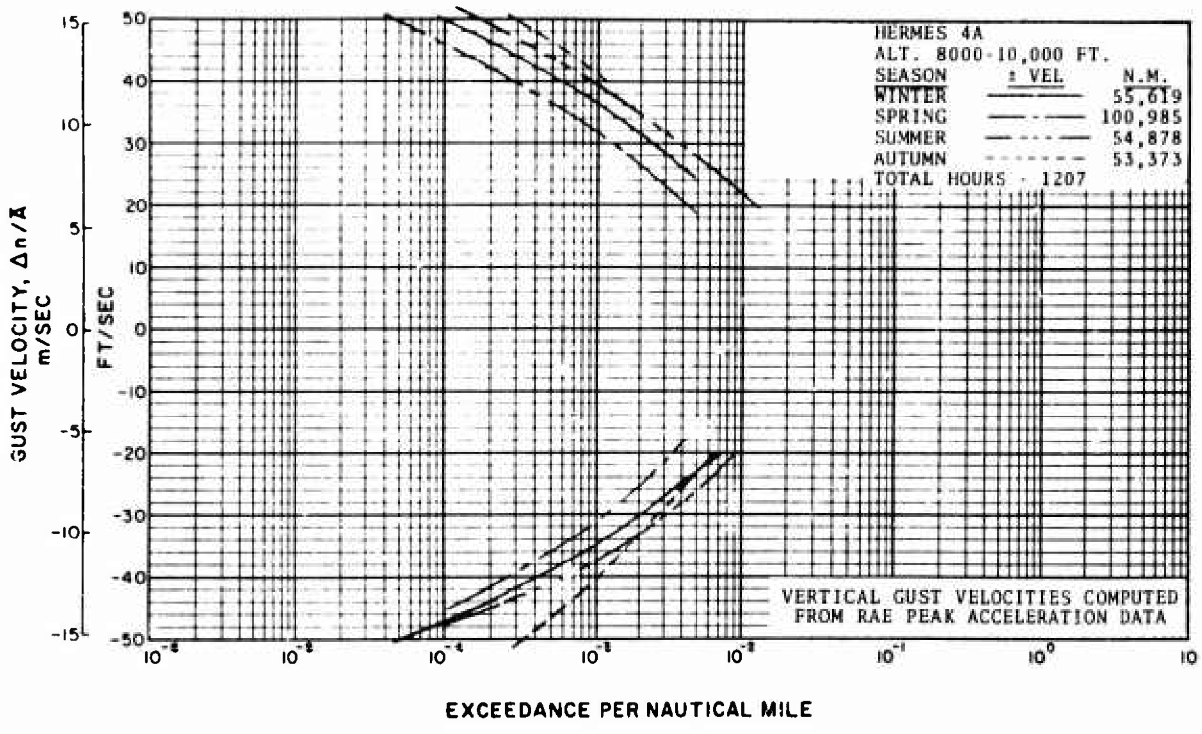

HERMES 4
ALT. 18,000-22,000 FT.
SEASON ± VEL N.M.
WINTER 3,146
SPRING 25,282
SUMMER 4,881
AUTUMN 3,307
TOTAL HOURS - 141
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

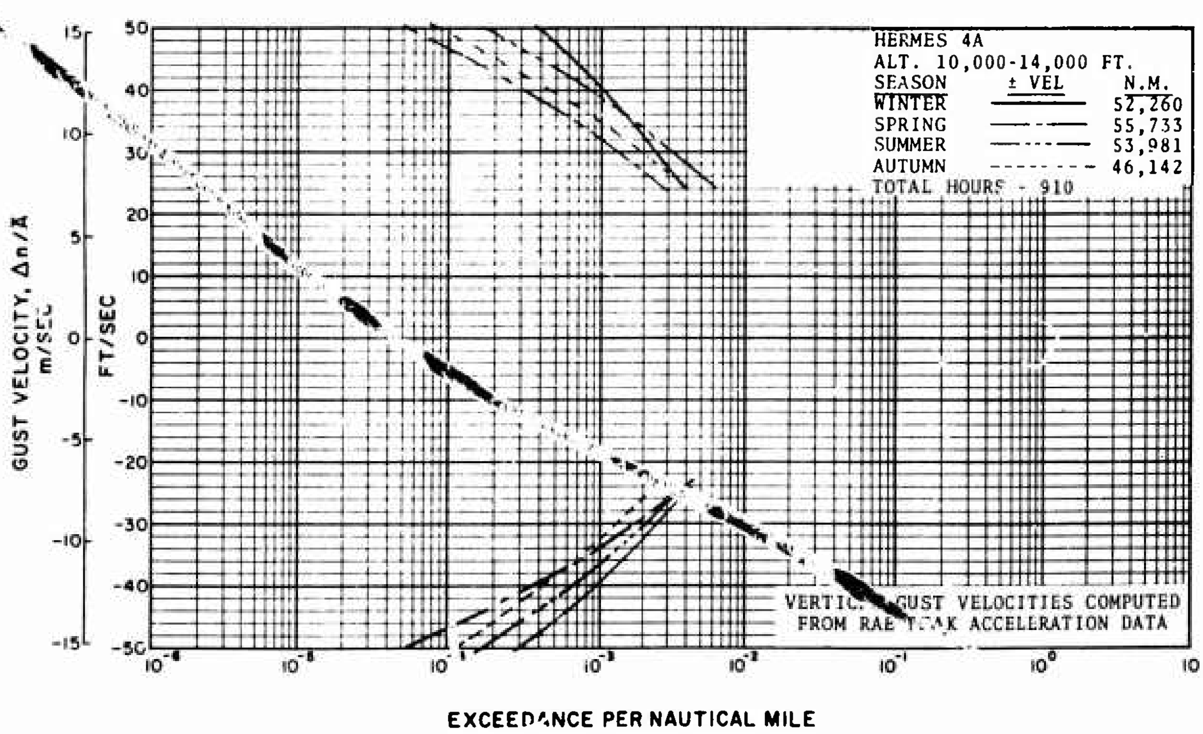

HERMES 4A
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 2,679
SPRING 3,567
SUMMER 2,841
AUTUMN 3,058
TOTAL HOURS - 75
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

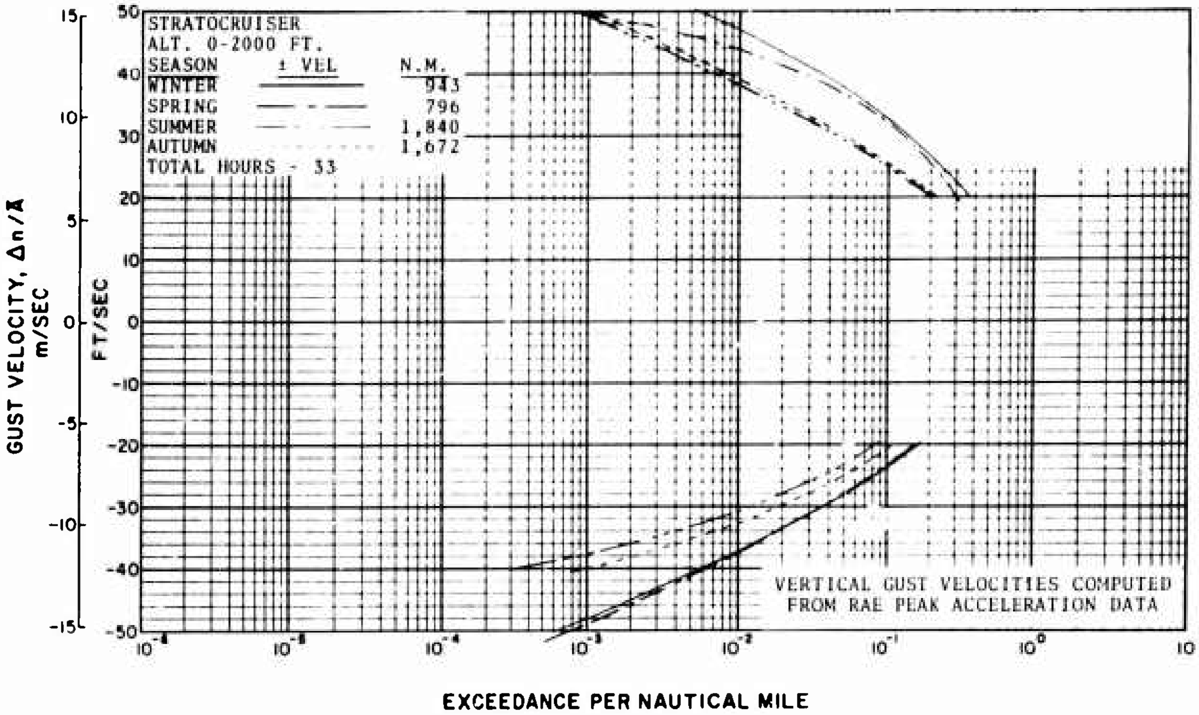

HERMES 4A
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 3,448
SPRING 4,844
SUMMER 3,472
AUTUMN 3,072
TOTAL HOURS - 85
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

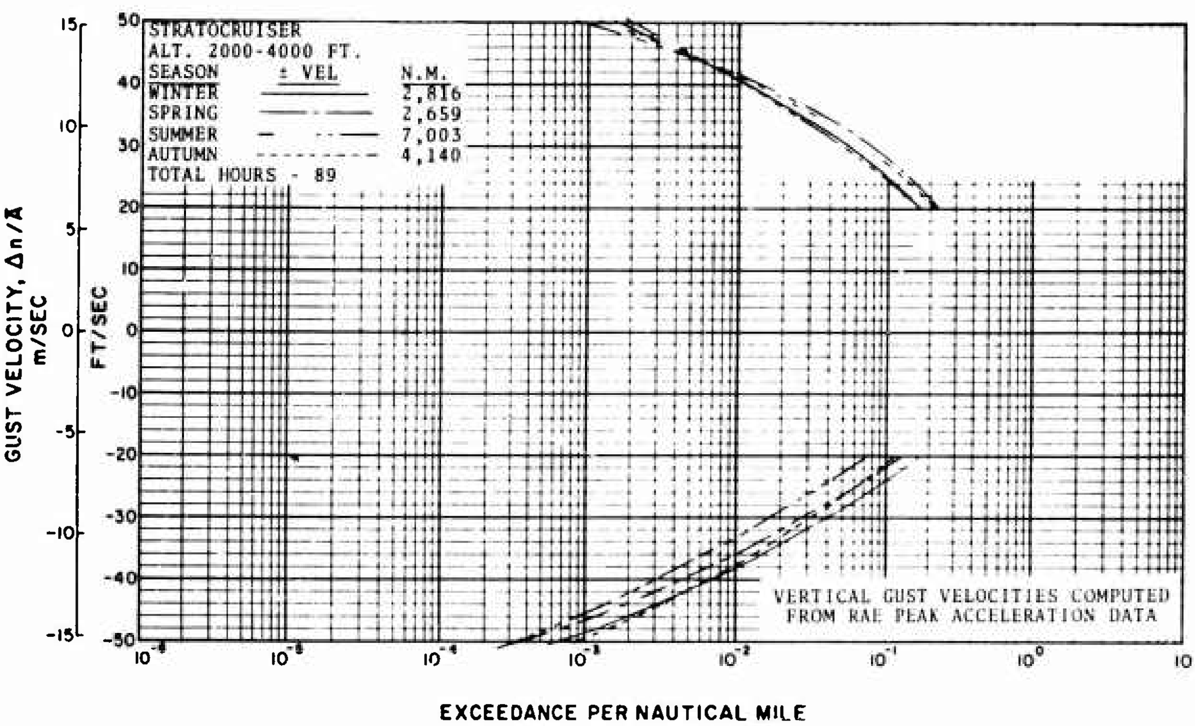

HERMES 4A
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 2,794
SPRING 3,844
SUMMER 2,934
AUTUMN 3,348
TOTAL HOURS - 64
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

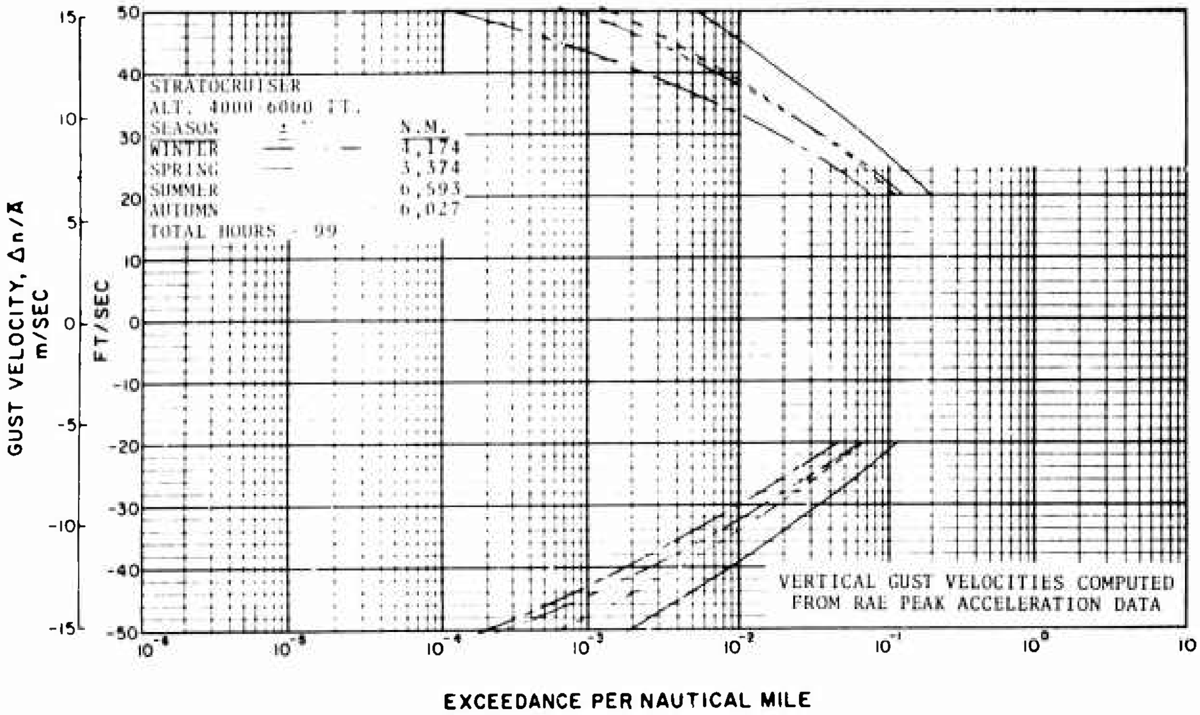

HERMES 4A
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 4,365
SPRING 6,169
SUMMER 5,721
AUTUMN 4,676
TOTAL HOURS - 97
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

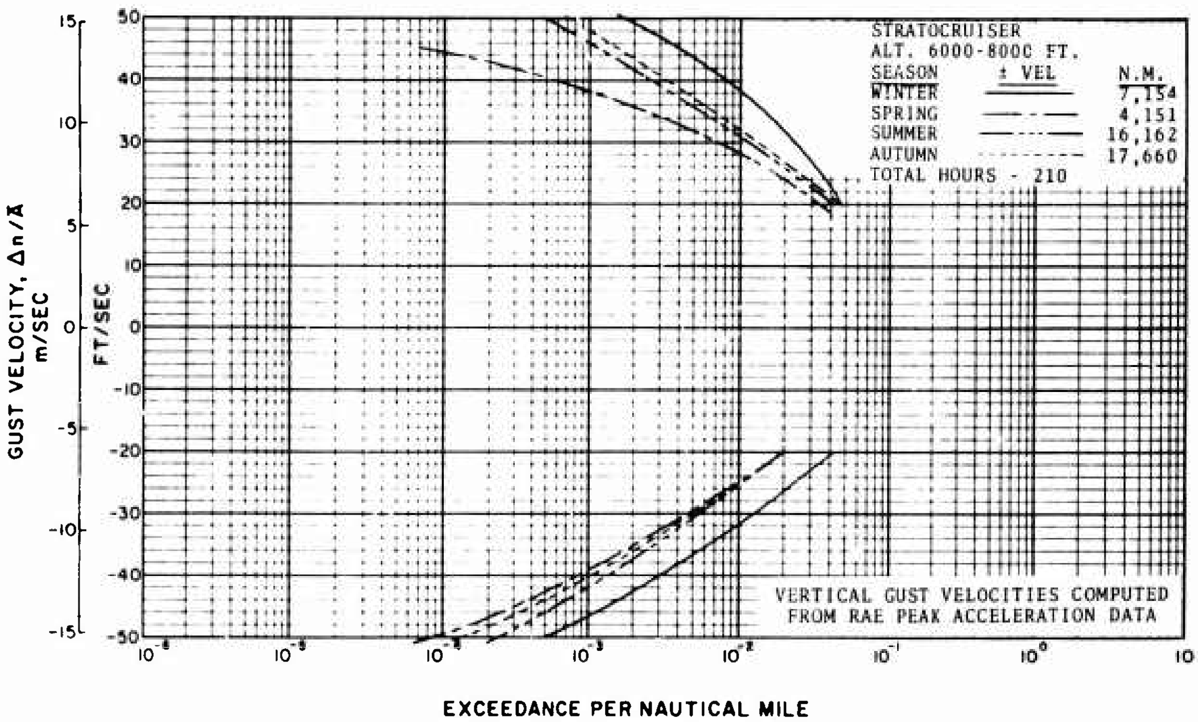

HERMES 4A
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 55,619
SPRING 100,985
SUMMER 54,878
AUTUMN 53,373
TOTAL HOURS - 1207
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

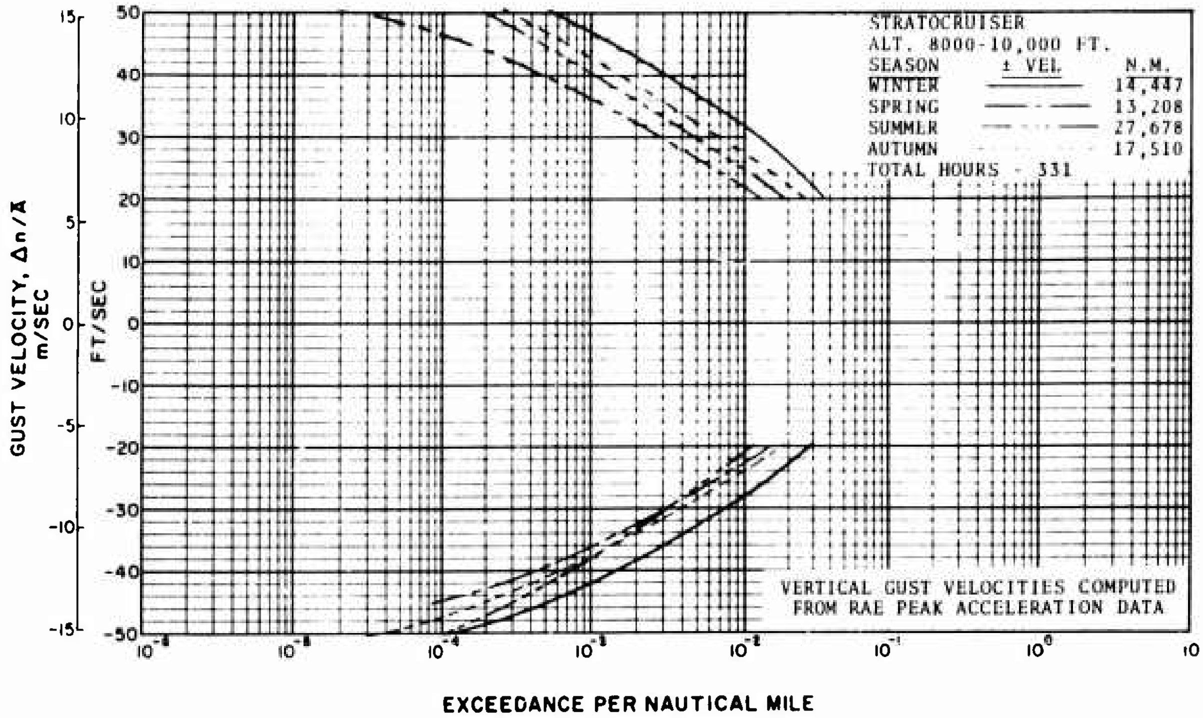

HERMES 4A
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 52,260
SPRING 55,733
SUMMER 53,981
AUTUMN 46,142
TOTAL HOURS - 910
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

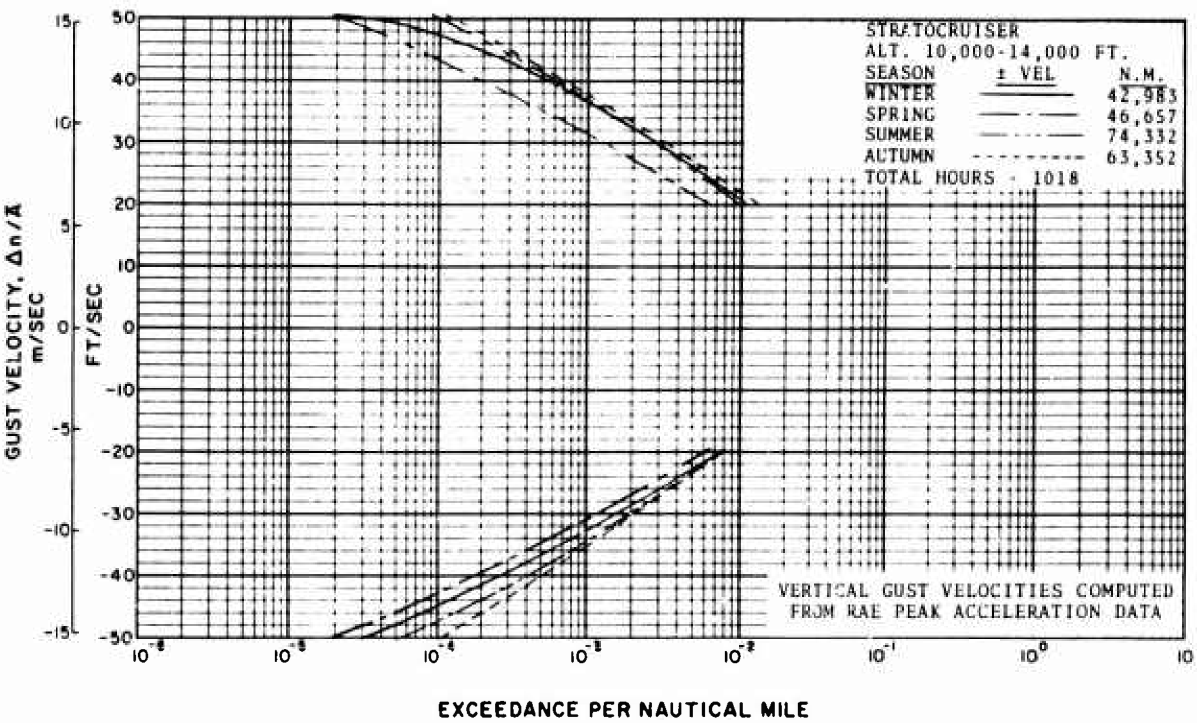

STRATOCRUISER
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 943
SPRING 796
SUMMER 1,840
AUTUMN 1,672
TOTAL HOURS - 33
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

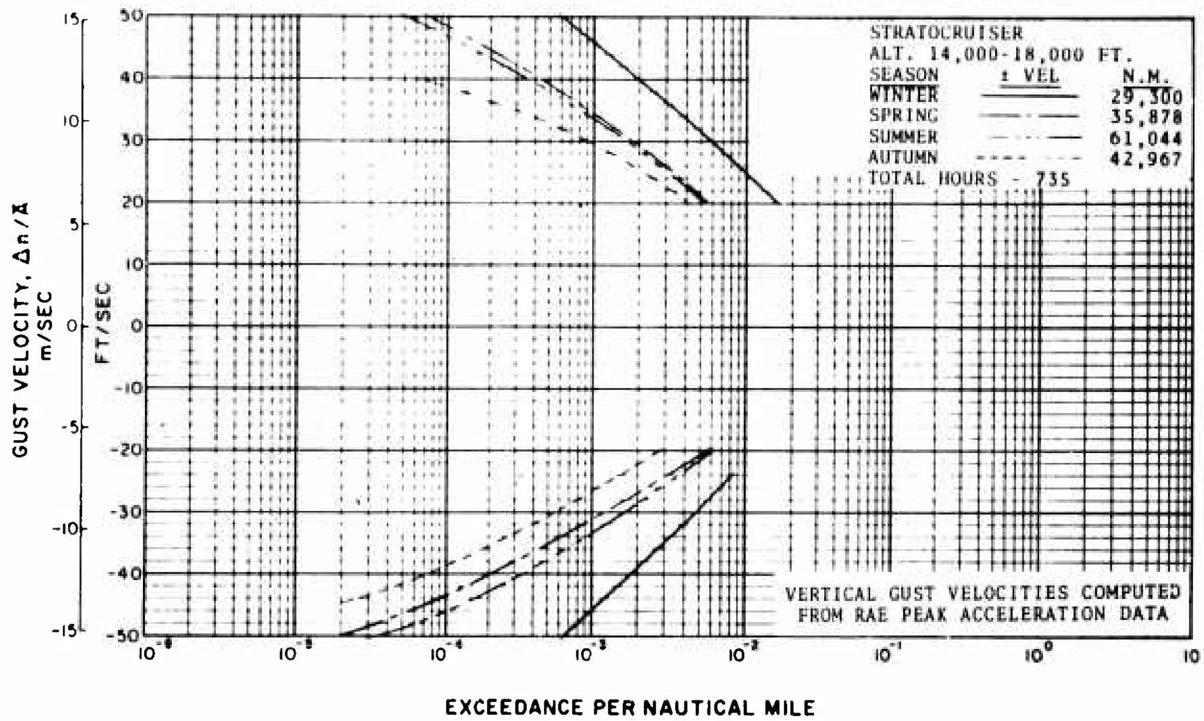

STRATOCRUISER
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 2,816
SPRING 2,659
SUMMER 7,003
AUTUMN 4,140
TOTAL HOURS - 89
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

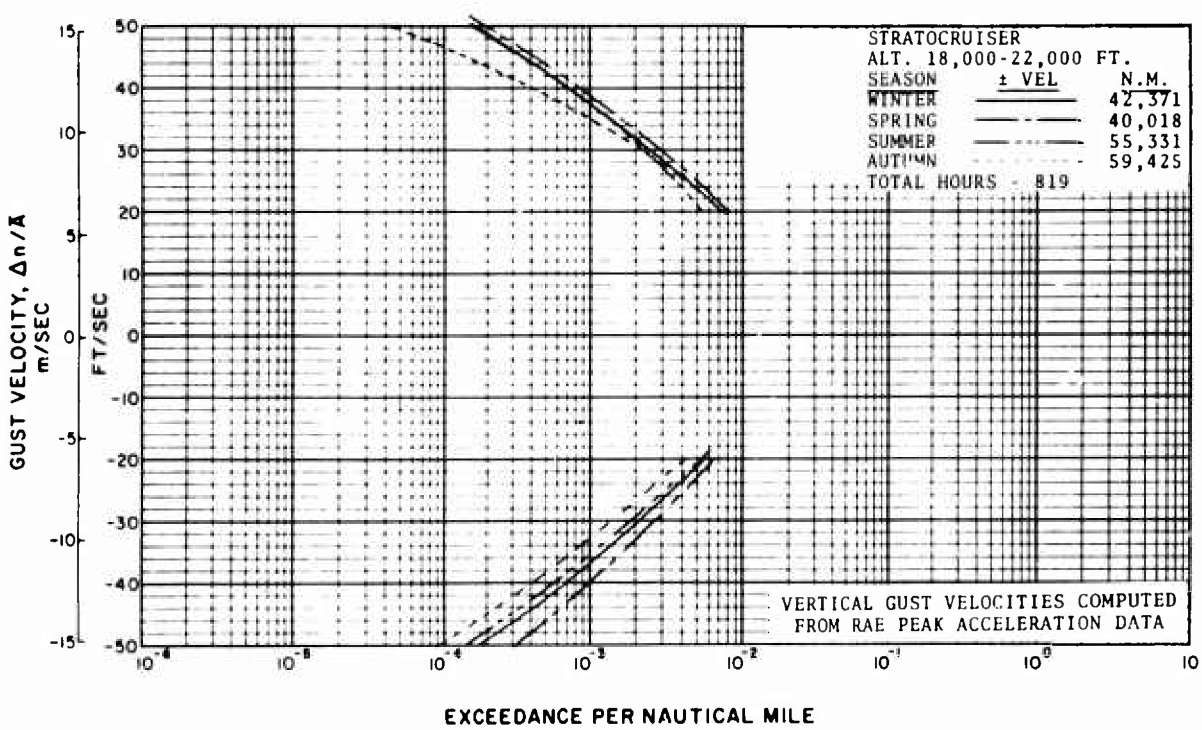

STRATOCRUISER
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 1,174
SPRING 3,374
SUMMER 6,593
AUTUMN 6,027
TOTAL HOURS - 99
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

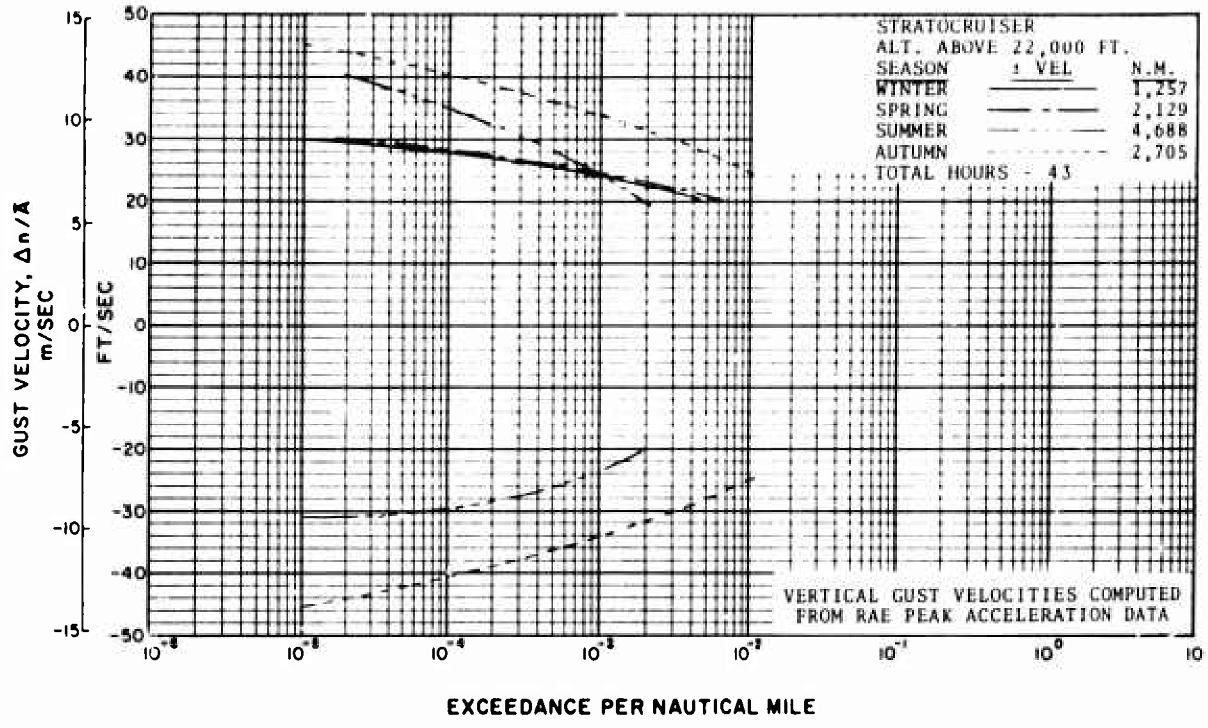

STRATOCRUISER
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 7,154
SPRING 4,151
SUMMER 16,162
AUTUMN 17,660
TOTAL HOURS - 210
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

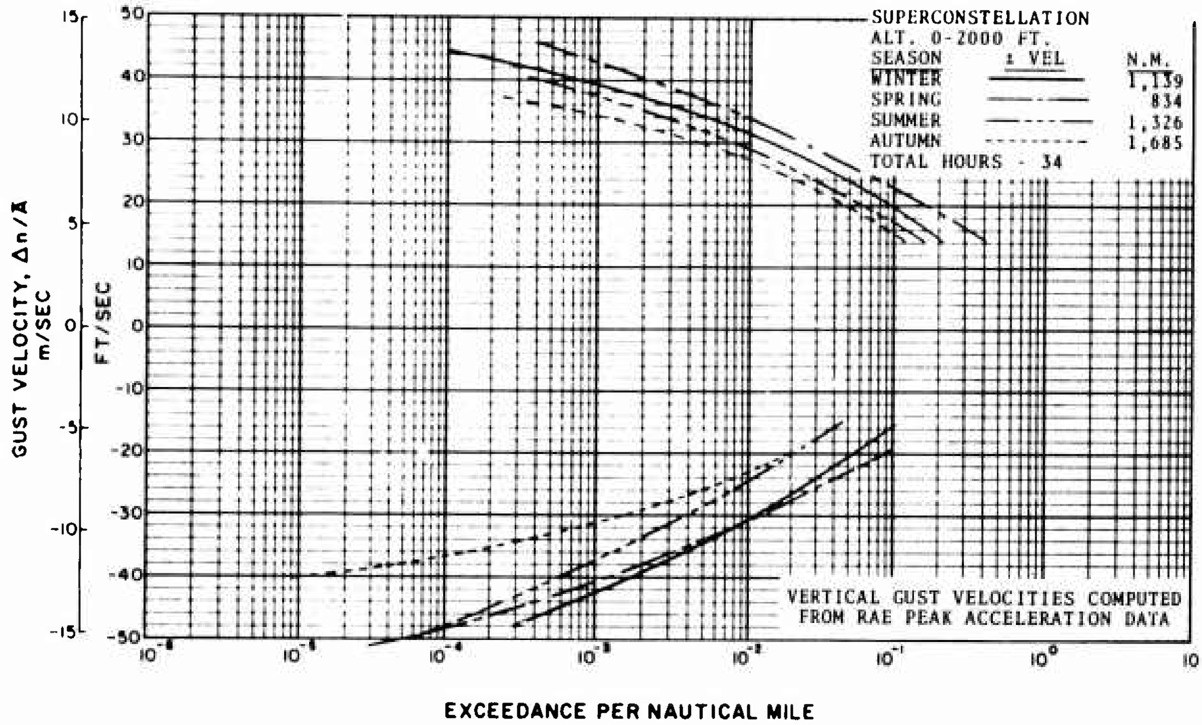

STRATOCRUISER
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 14,447
SPRING 13,208
SUMMER 27,678
AUTUMN 17,510
TOTAL HOURS - 331
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


STRATOCRUISER
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 42,983
SPRING 46,657
SUMMER 74,332
AUTUMN 63,352
TOTAL HOURS - 1018
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

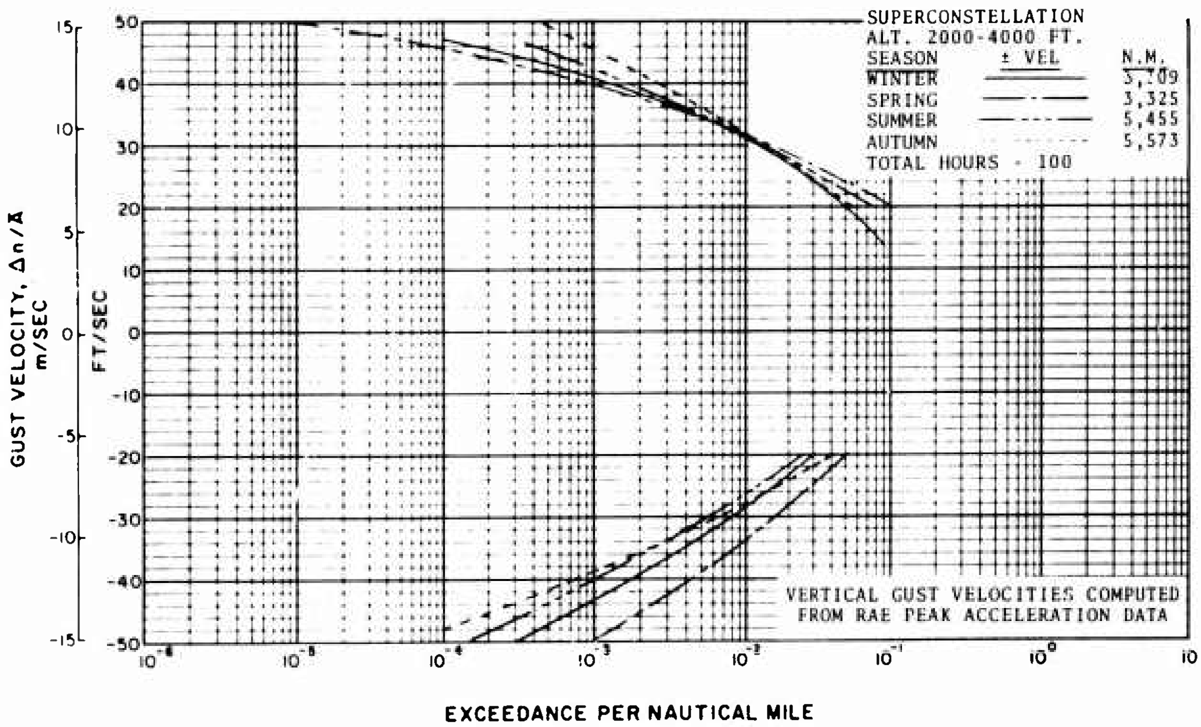

STRATOCRUISER
ALT. 14,000-18,000 FT.
SEASON ± VEL N.M.
WINTER 29,300
SPRING 35,878
SUMMER 61,044
AUTUMN 42,967
TOTAL HOURS - 735
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


STRATOCRUISER
ALT. 18,000-22,000 FT.
SEASON ± VEL N.M.
WINTER 42,371
SPRING 40,018
SUMMER 55,331
AUTUMN 59,425
TOTAL HOURS - 819
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

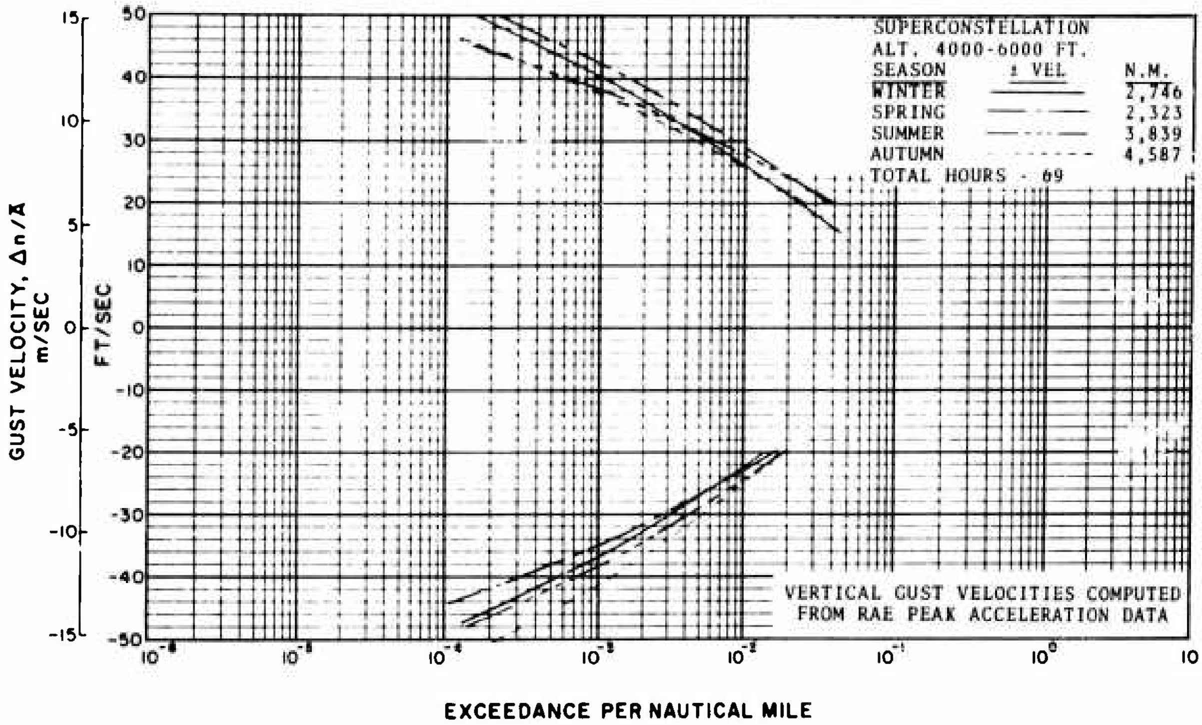

STRATOCRUISER
ALT. ABOVE 22,000 FT.
SEASON ± VEL N.M.
WINTER 1,257
SPRING 2,129
SUMMER 4,688
AUTUMN 2,705
TOTAL HOURS - 43
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

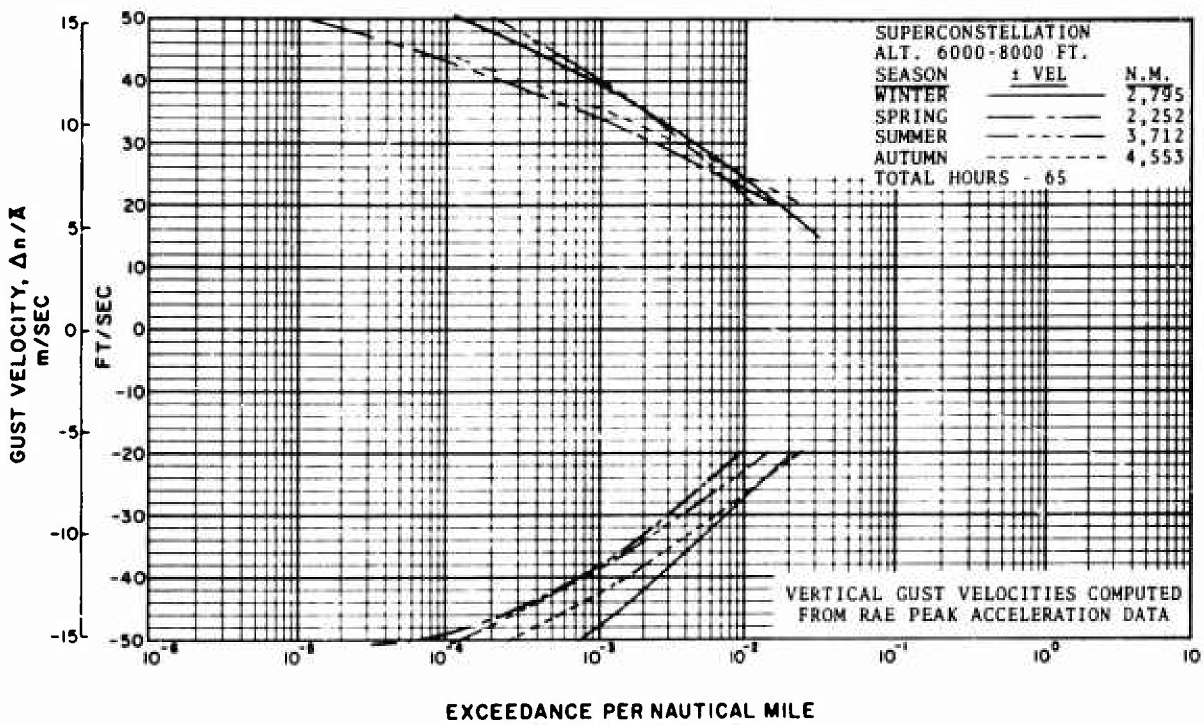


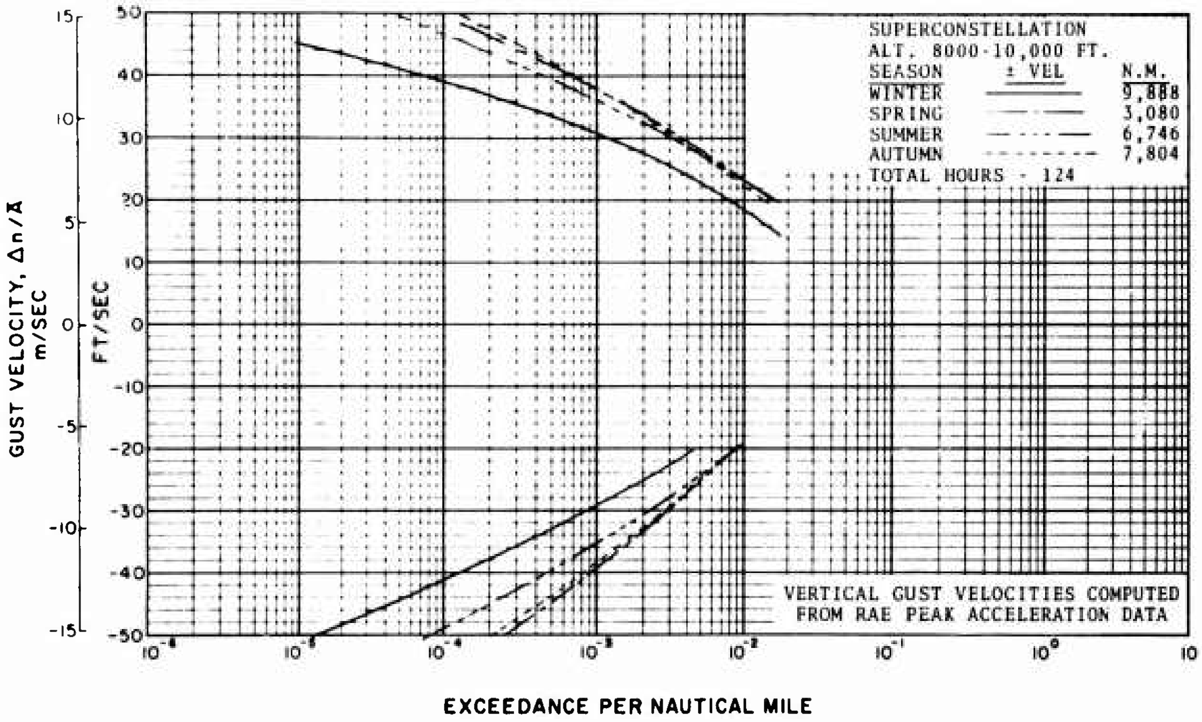
SUPERCONSTELLATION
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 1,139
SPRING 834
SUMMER 1,326
AUTUMN 1,685
TOTAL HOURS - 34
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

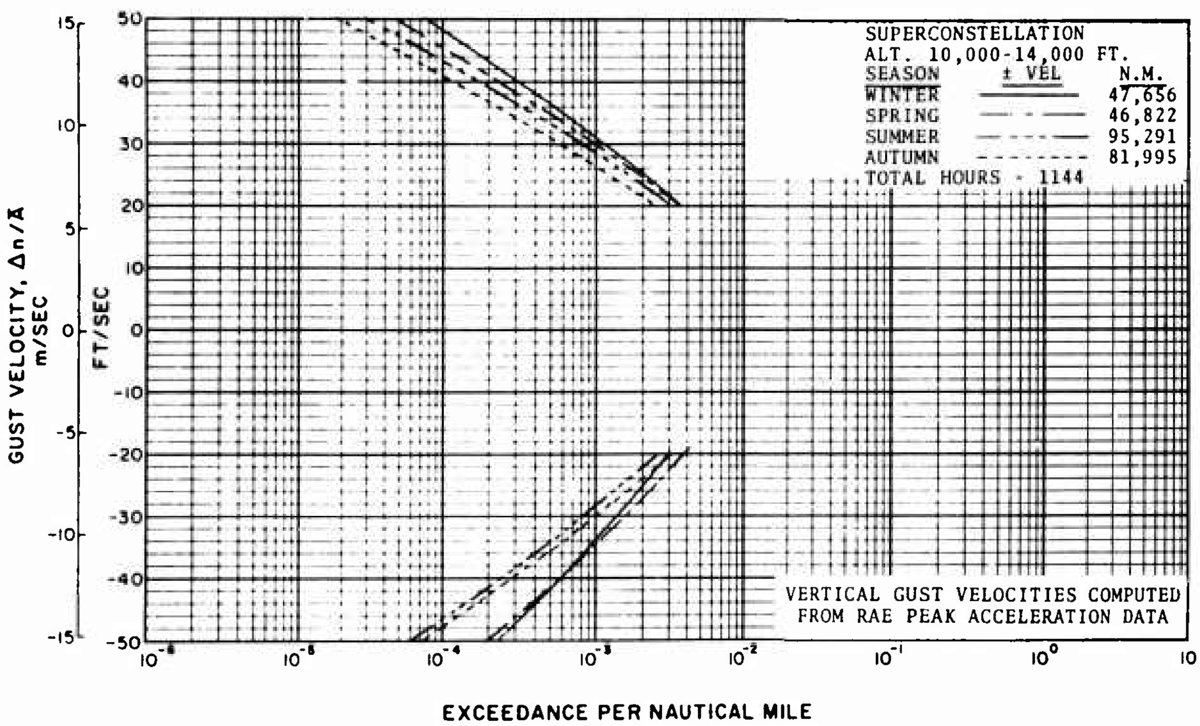


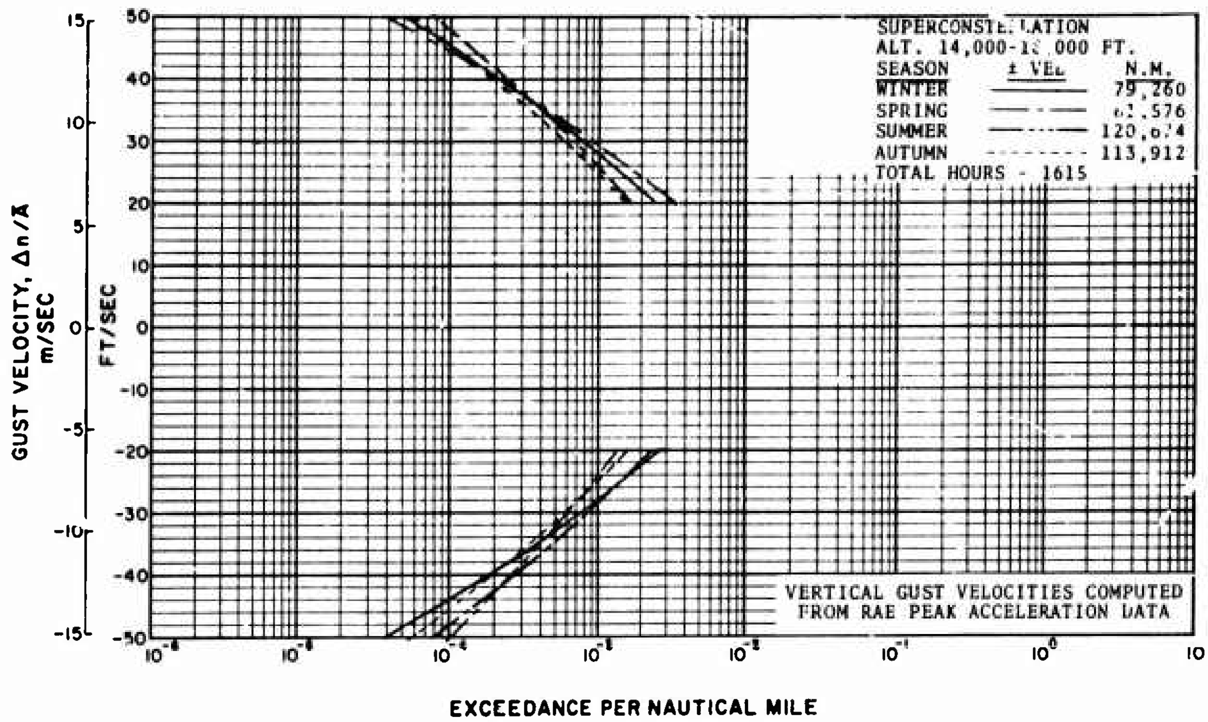
SUPERCONSTELLATION
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 3,709
SPRING 3,325
SUMMER 5,455
AUTUMN 5,573
TOTAL HOURS - 100
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

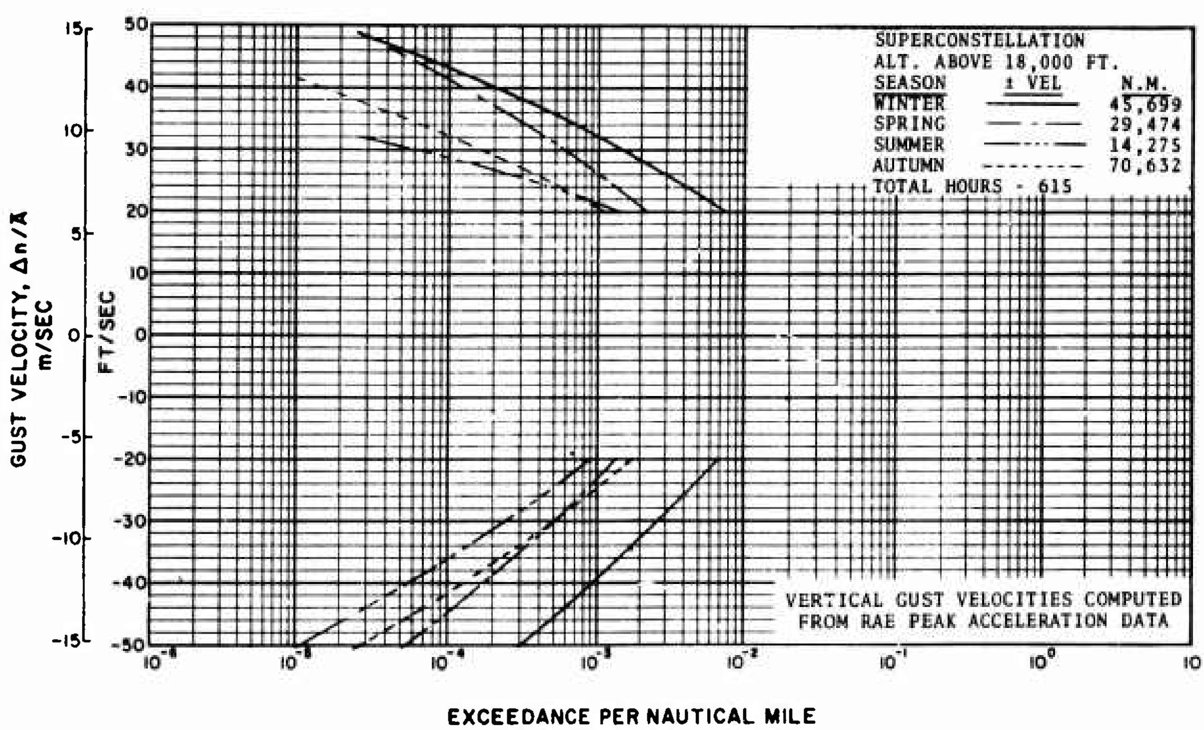

SUPERCONSTELLATION
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 2,746
SPRING 2,323
SUMMER 3,839
AUTUMN 4,587
TOTAL HOURS - 69
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

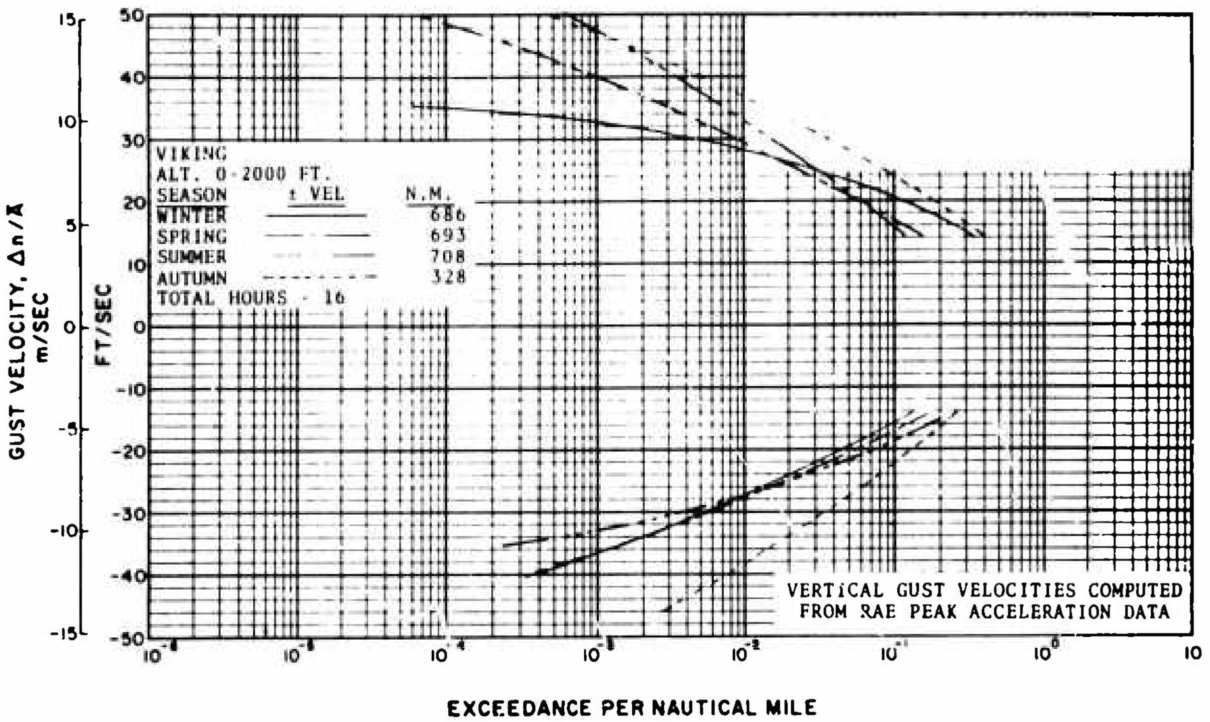

SUPERCONSTELLATION
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 2,795
SPRING 2,252
SUMMER 3,712
AUTUMN 4,553
TOTAL HOURS - 65
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

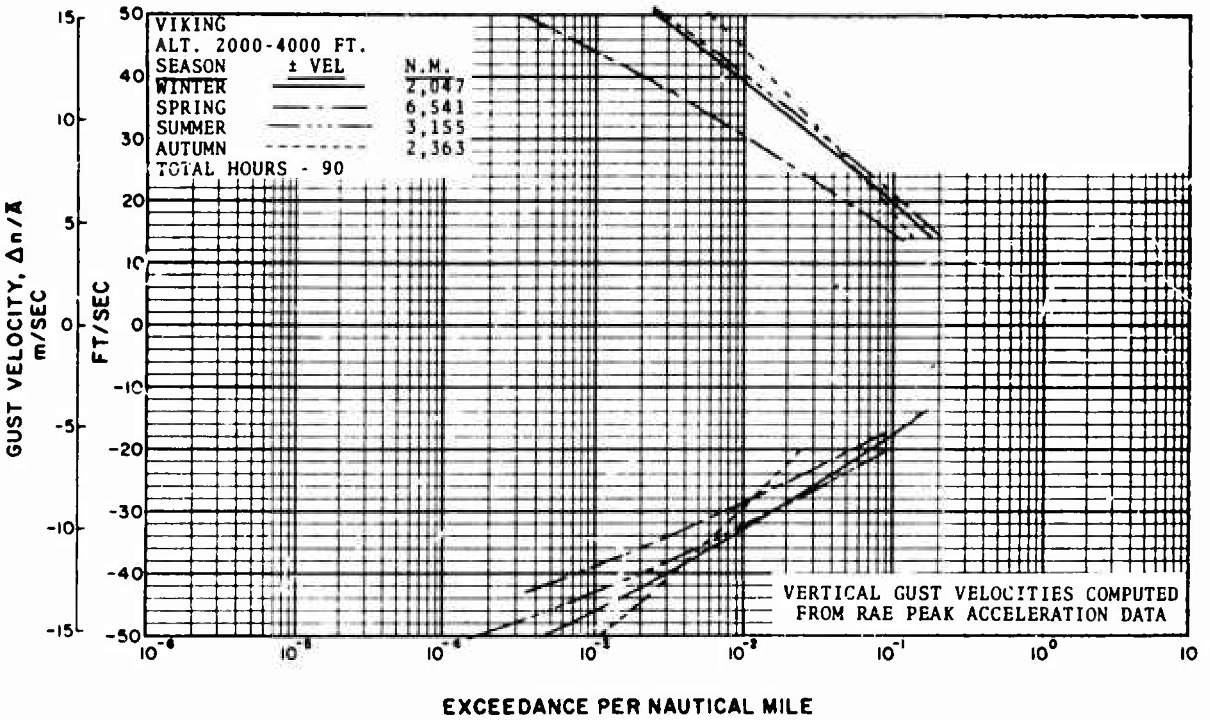

SUPERCONSTELLATION
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 9,888
SPRING 3,080
SUMMER 6,746
AUTUMN 7,804
TOTAL HOURS - 124
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

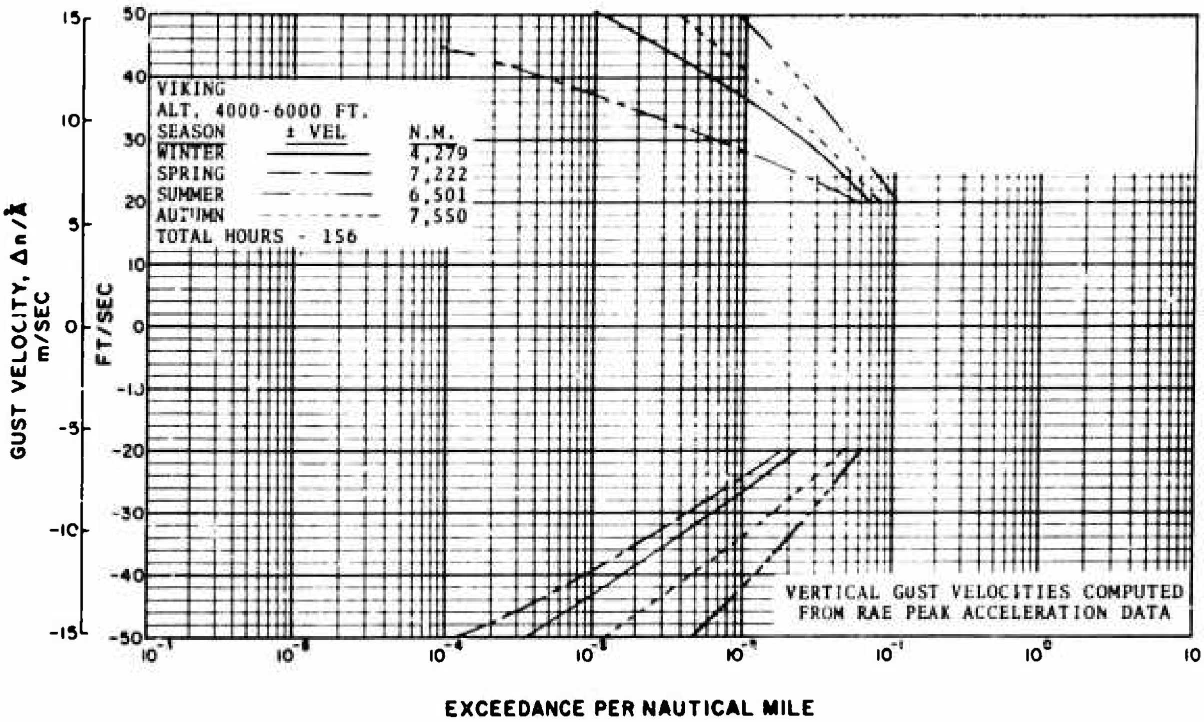

SUPERCONSTELLATION
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 47,656
SPRING 46,822
SUMMER 95,291
AUTUMN 81,995
TOTAL HOURS - 1144
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

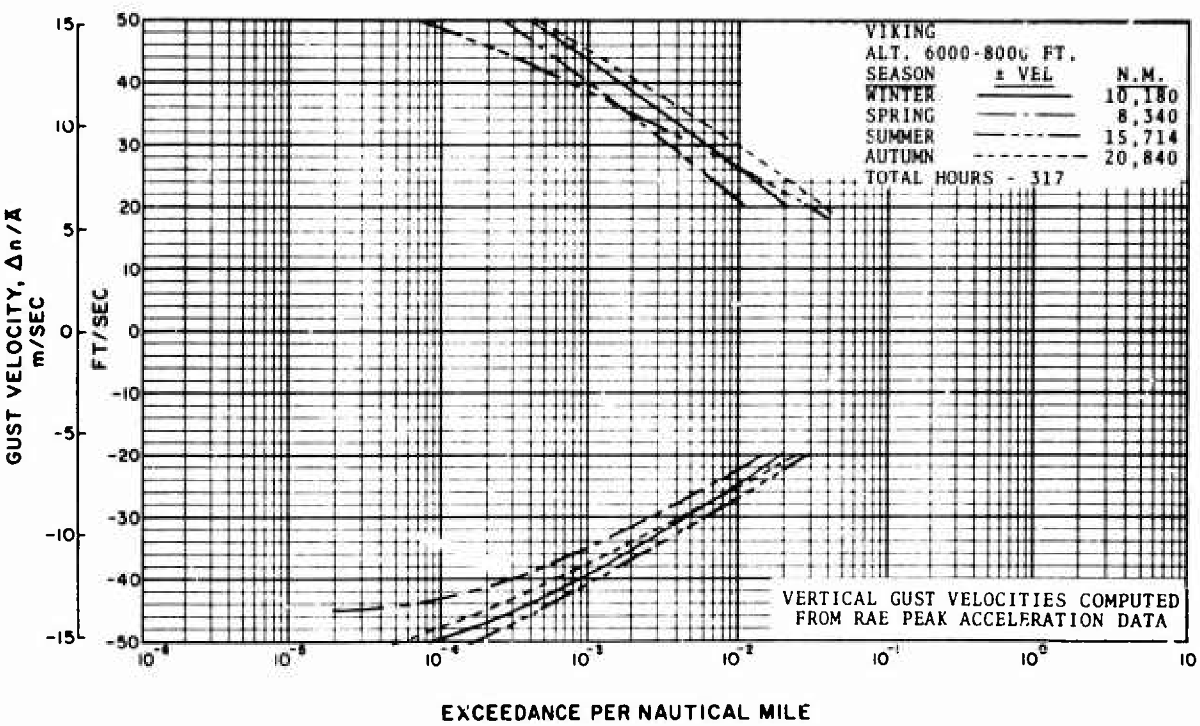

SUPERCONSTELLATION
ALT. 14,000-
FT.
SEASON
± VEL
N.M.
WINTER
79,260
SPRING
SUMMER
AUTUMN
113,912
TOTAL HOURS - 1615
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

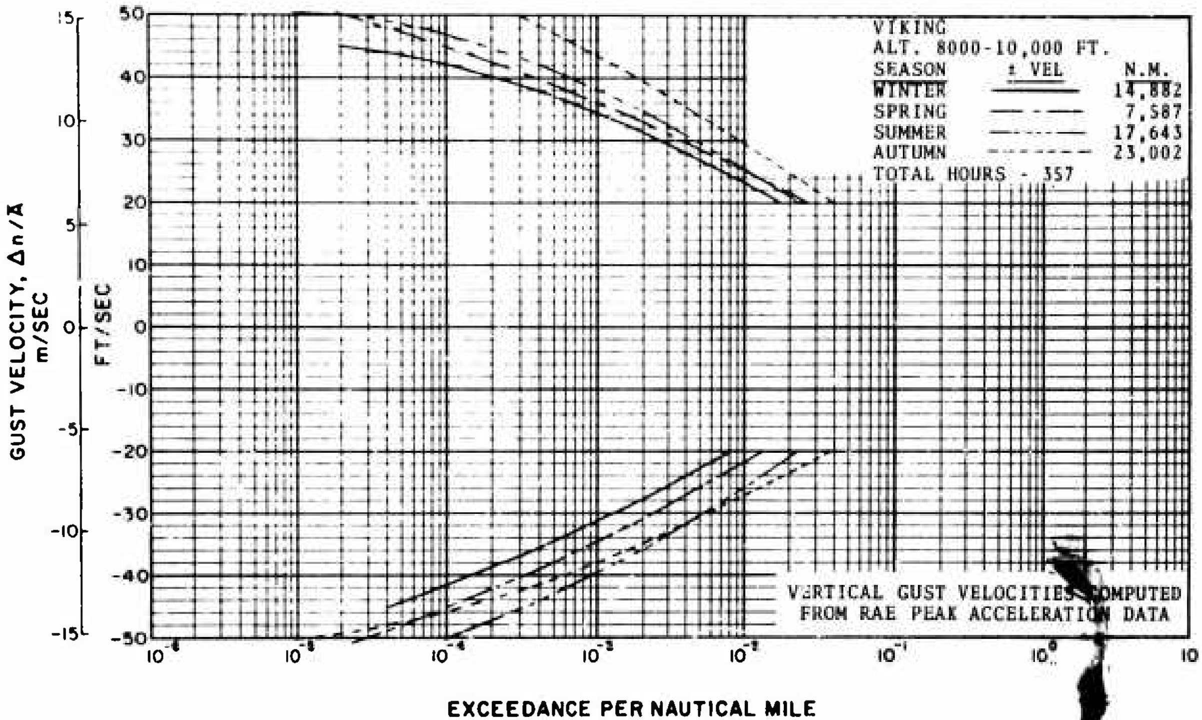

SUPERCONSTELLATION
ALT. ABOVE 18,000 FT.
SEASON
± VEL
N.M.
WINTER
45,699
SPRING
29,474
SUMMER
14,275
AUTUMN
70,632
TOTAL HOURS - 615
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

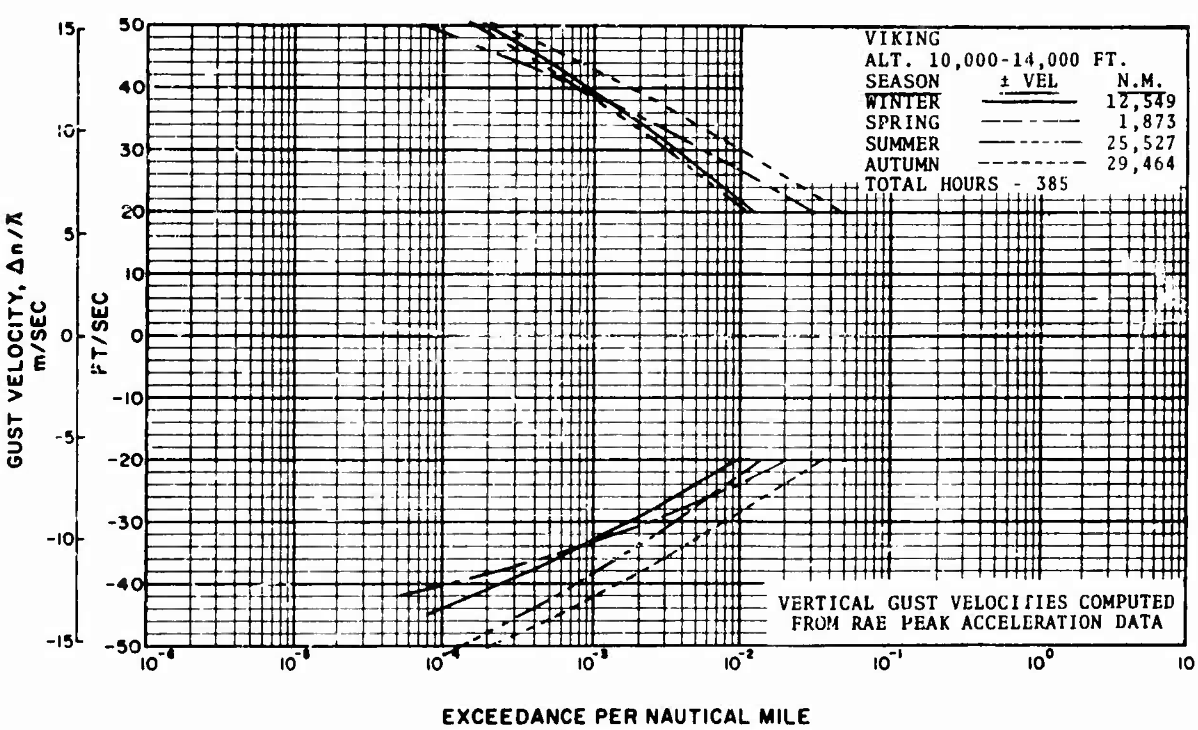

VIKING
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 686
SPRING 693
SUMMER 708
AUTUMN 328
TOTAL HOURS - 16
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

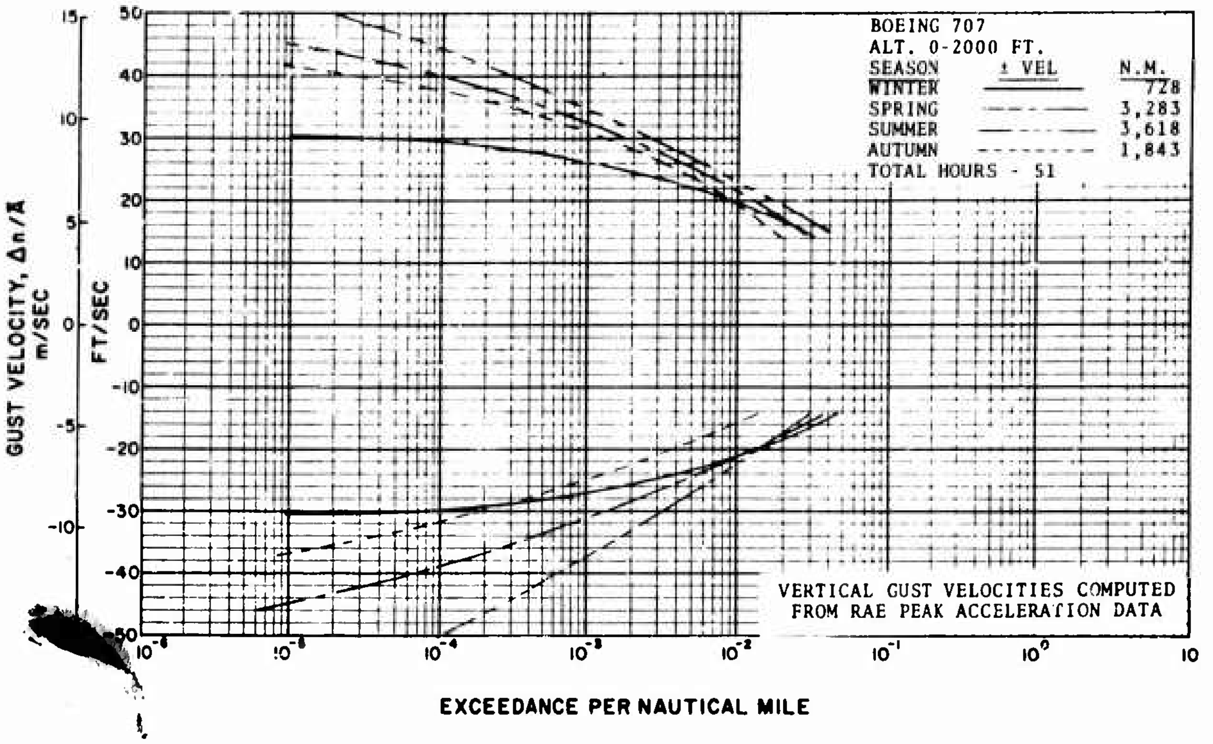

VIKING
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 2,047
SPRING 6,541
SUMMER 3,155
AUTUMN 2,363
TOTAL HOURS - 90
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

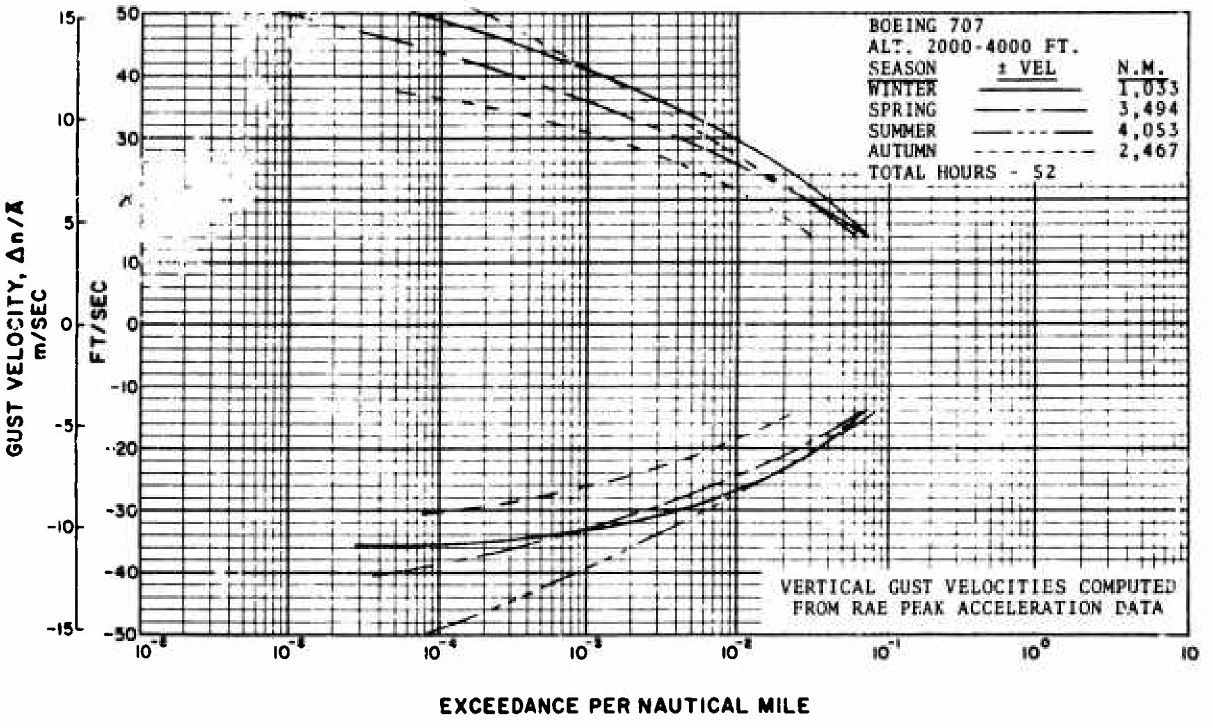

VIKING
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 4,279
SPRING 7,222
SUMMER 6,501
AUTUMN 7,550
TOTAL HOURS - 156
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

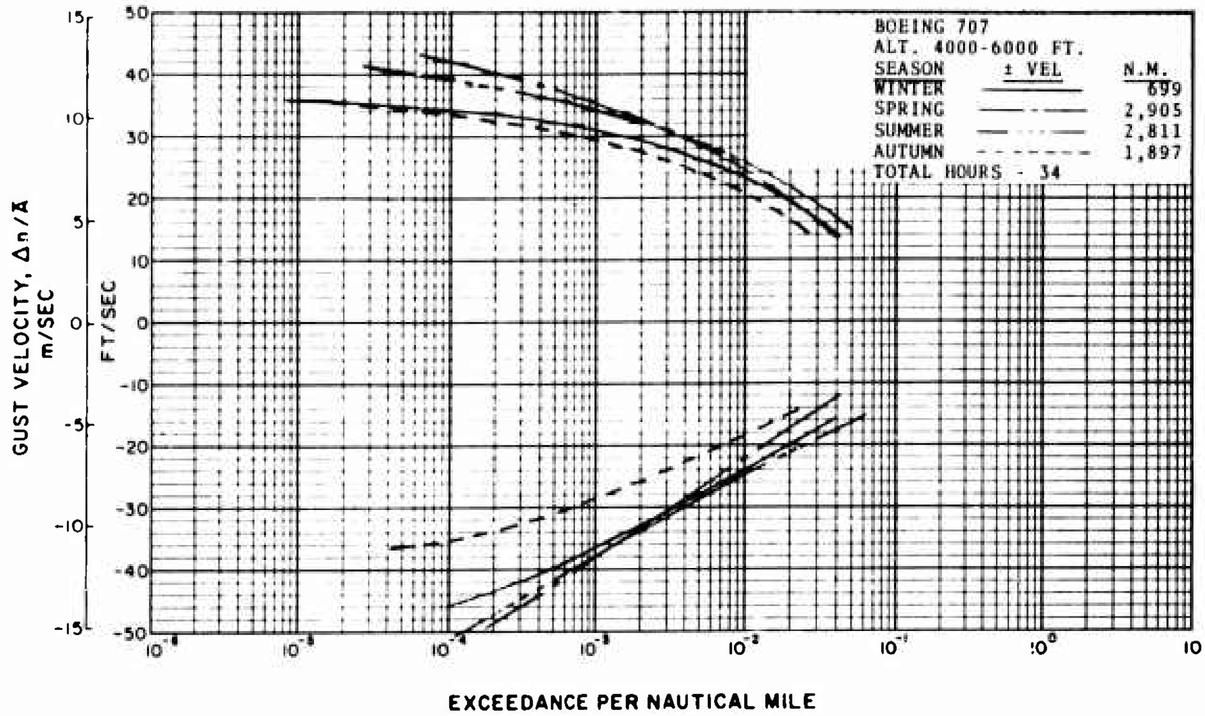

VIKING
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 10,180
SPRING 8,340
SUMMER 15,714
AUTUMN 20,840
TOTAL HOURS - 317
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

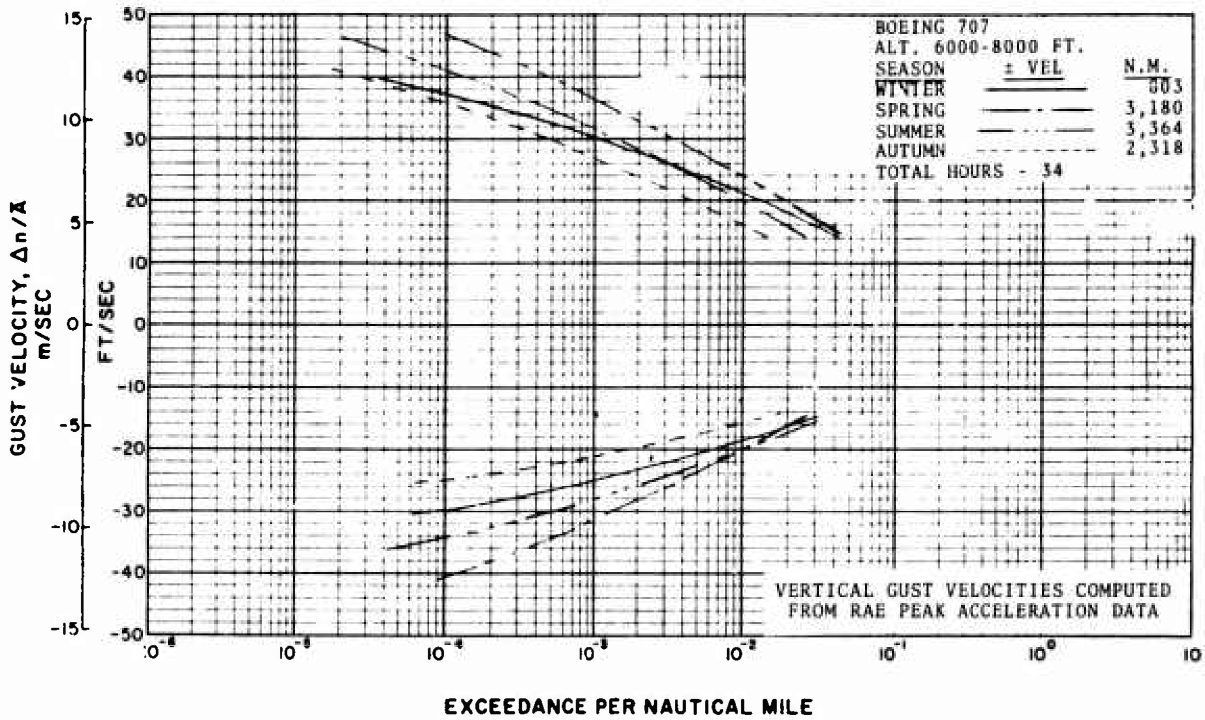

VIKING
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 14,882
SPRING 7,587
SUMMER 17,643
AUTUMN 23,002
TOTAL HOURS - 357
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

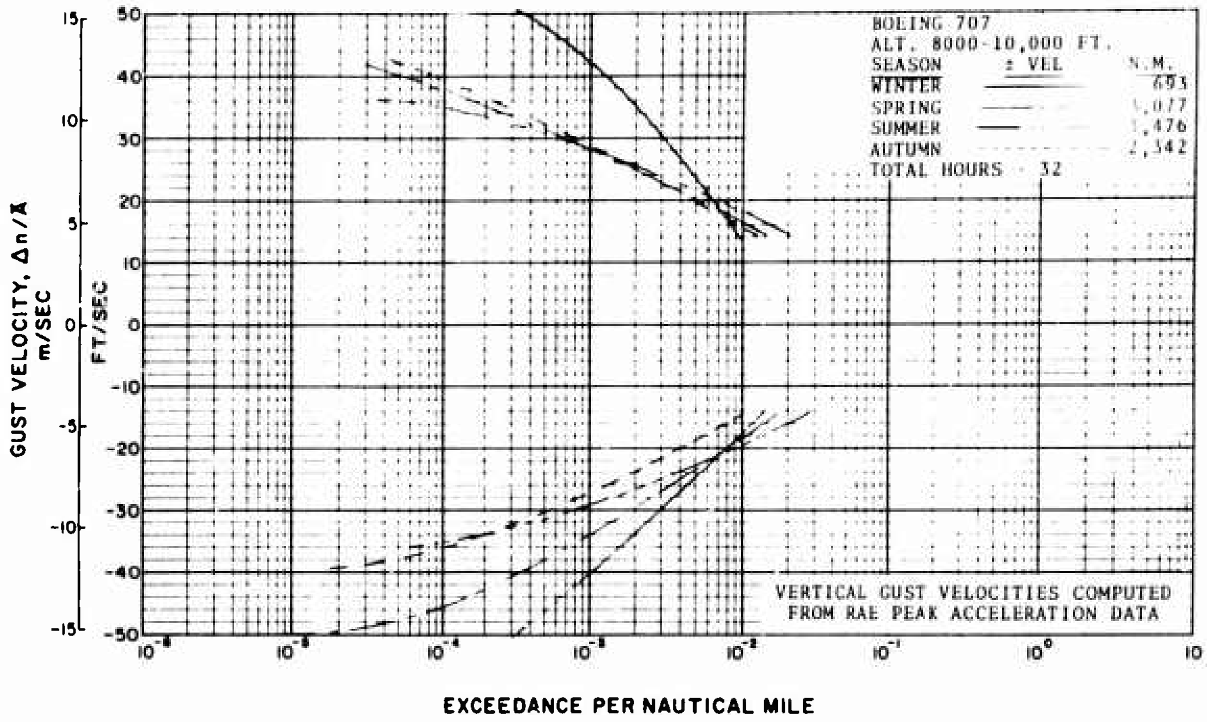

VIKING
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 12,549
SPRING 1,873
SUMMER 25,527
AUTUMN 29,464
TOTAL HOURS - 385
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

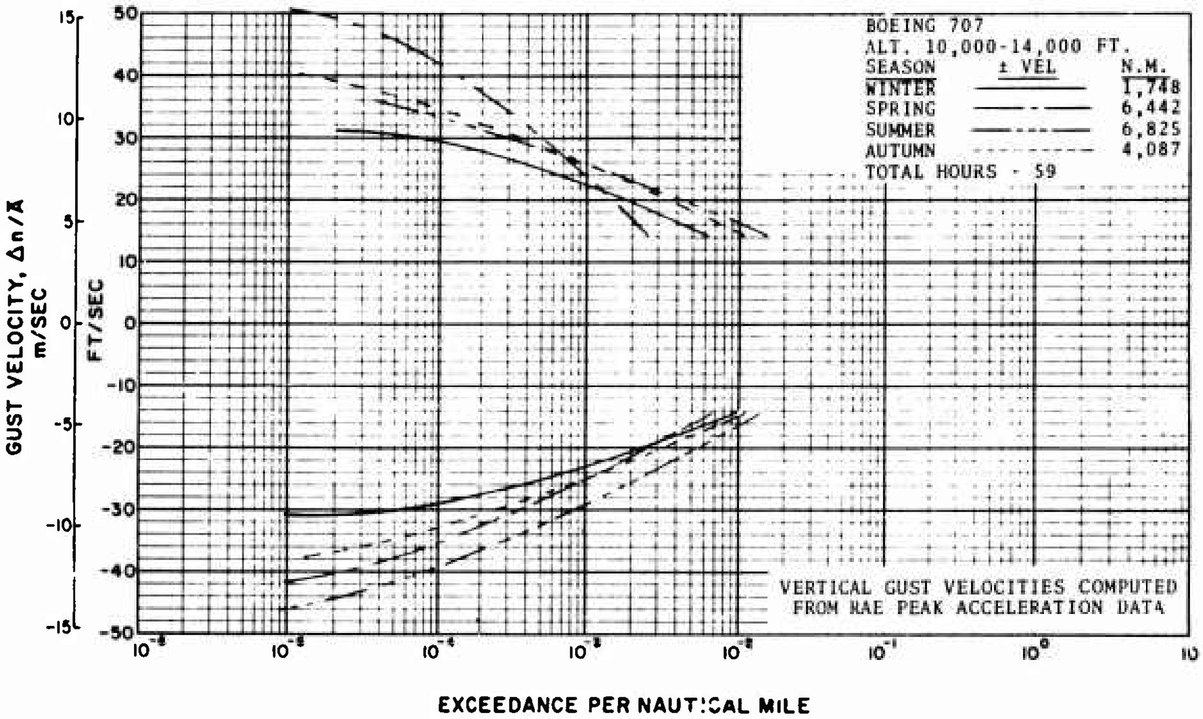

BOEING 707
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 728
SPRING 3,283
SUMMER 3,618
AUTUMN 1,843
TOTAL HOURS - 51
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

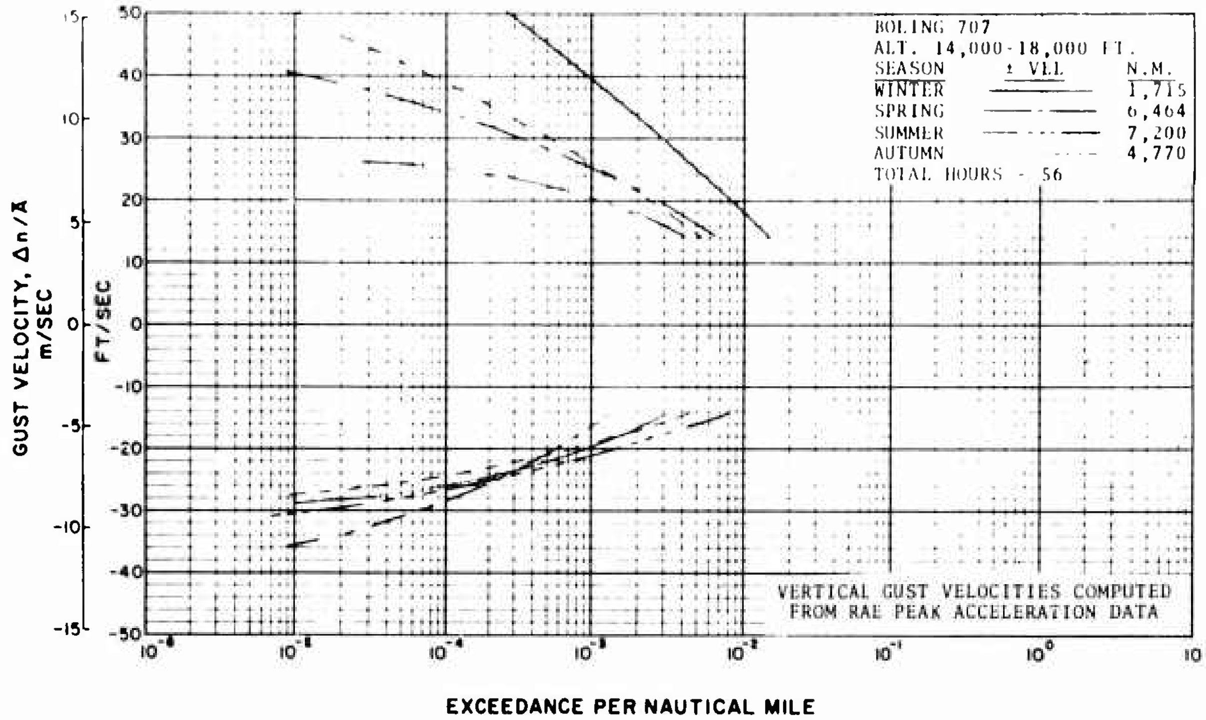

BOEING 707
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 1,033
SPRING 3,494
SUMMER 4,053
AUTUMN 2,467
TOTAL HOURS - 52
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

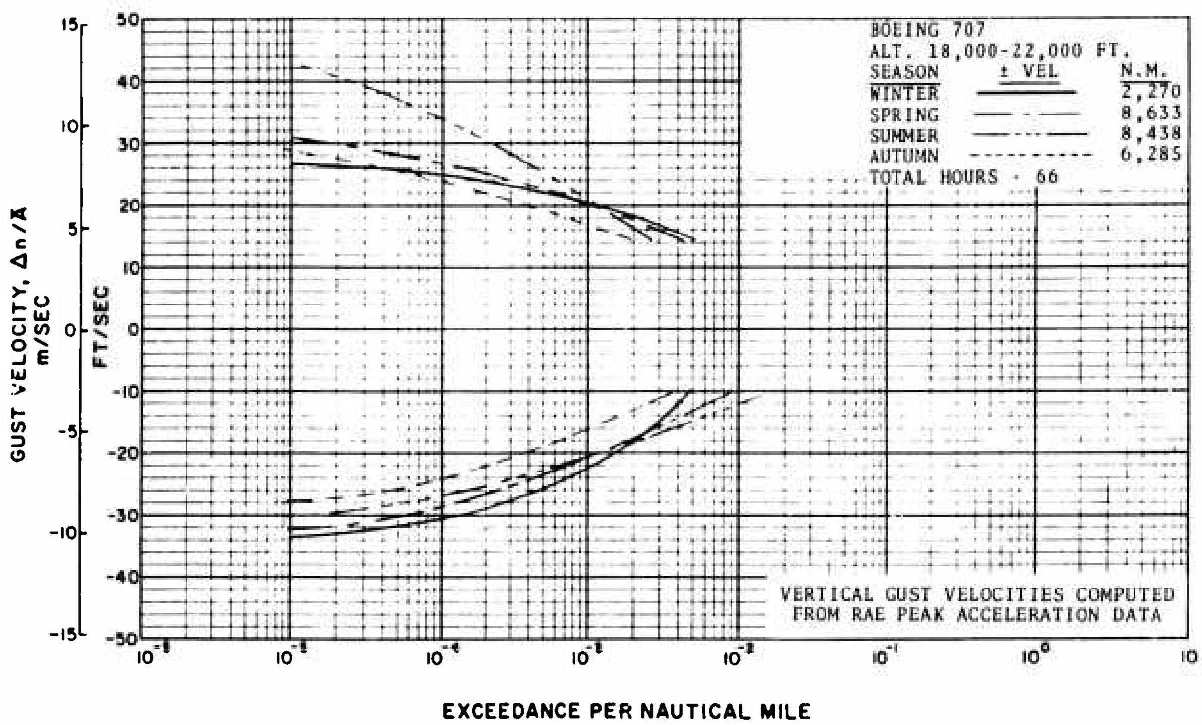

BOEING 707
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 699
SPRING 2,905
SUMMER 2,811
AUTUMN 1,897
TOTAL HOURS - 34
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

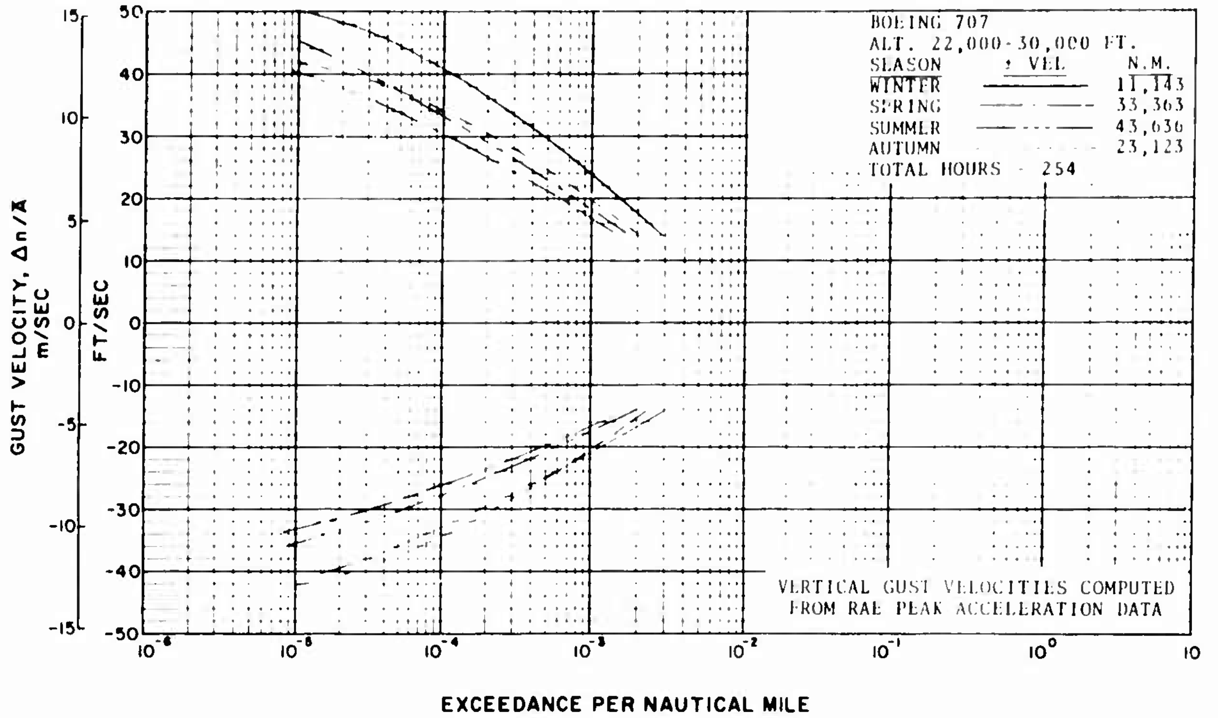

BOEING 707
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 803
SPRING 3,180
SUMMER 3,364
AUTUMN 2,318
TOTAL HOURS - 34
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

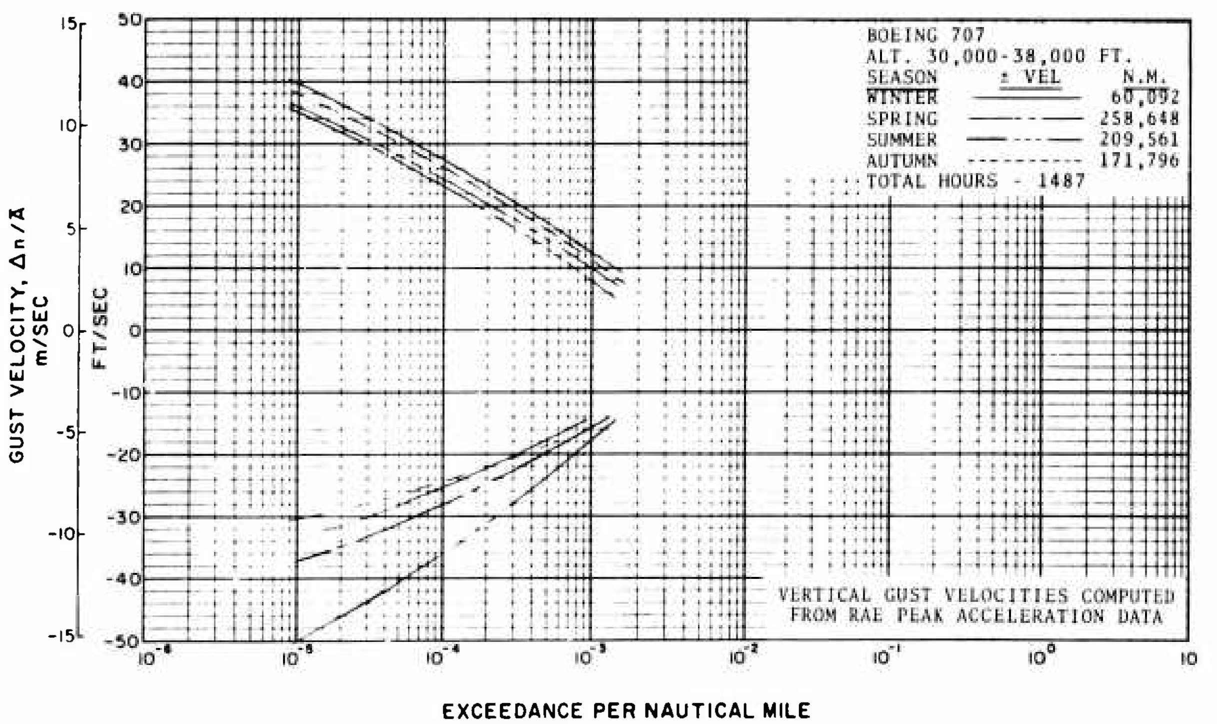

BOEING 707
ALT. 8000-10,000 FT.
SEASON
± VEL
N.M.
WINTER
693
SPRING
SUMMER
AUTUMN
TOTAL HOURS - 32
VERTICAL GUST VELOCITIES COMPUTED
FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā
m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

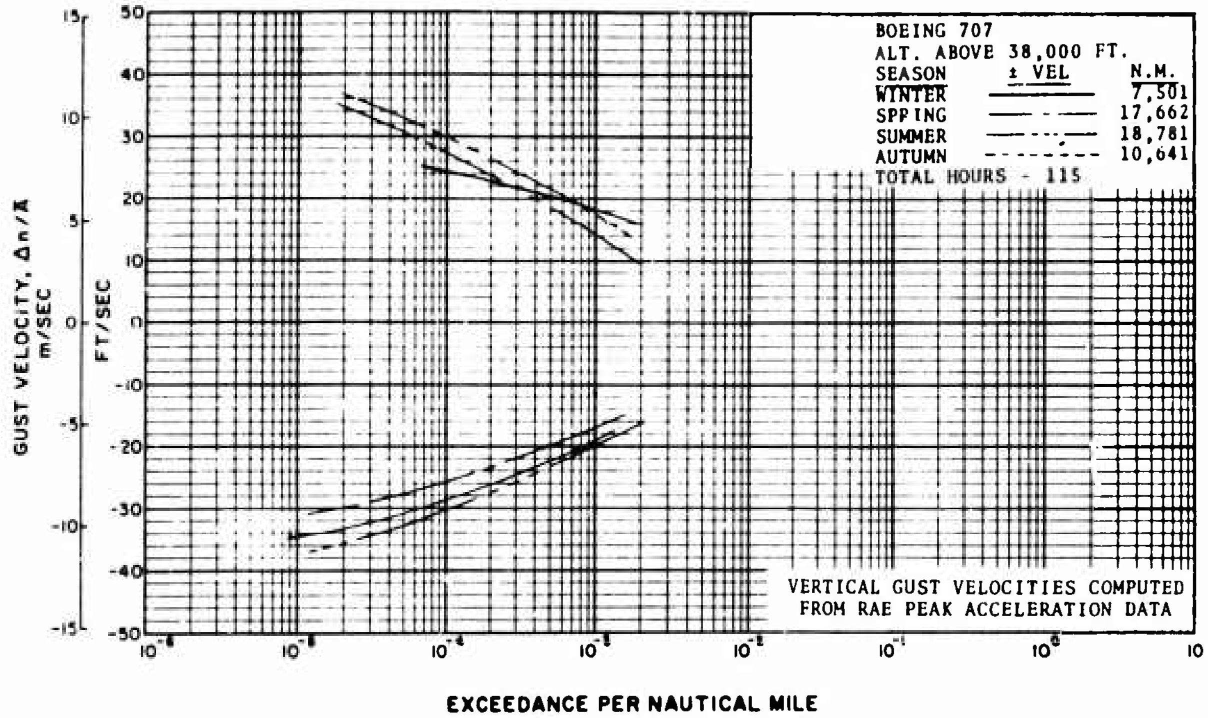

BOEING 707
ALT. 10,000-14,000 FT.
SEASON
± VEL
N.M.
WINTER
1,748
SPRING
6,442
SUMMER
6,825
AUTUMN
4,087
TOTAL HOURS - 59
VERTICAL GUST VELOCITIES COMPUTED
FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā
m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

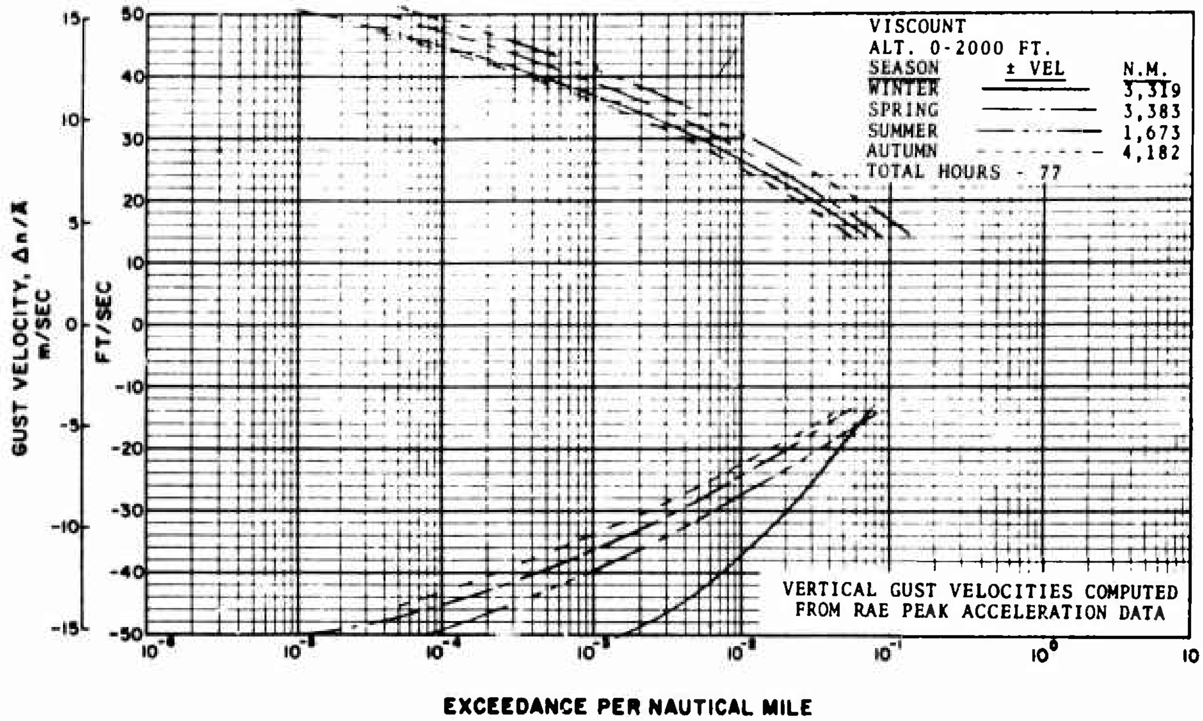

BOEING 707
ALT. 14,000-18,000 FT.
SEASON ± VEL N.M.
WINTER 1,715
SPRING 6,464
SUMMER 7,200
AUTUMN 4,770
TOTAL HOURS - 56
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

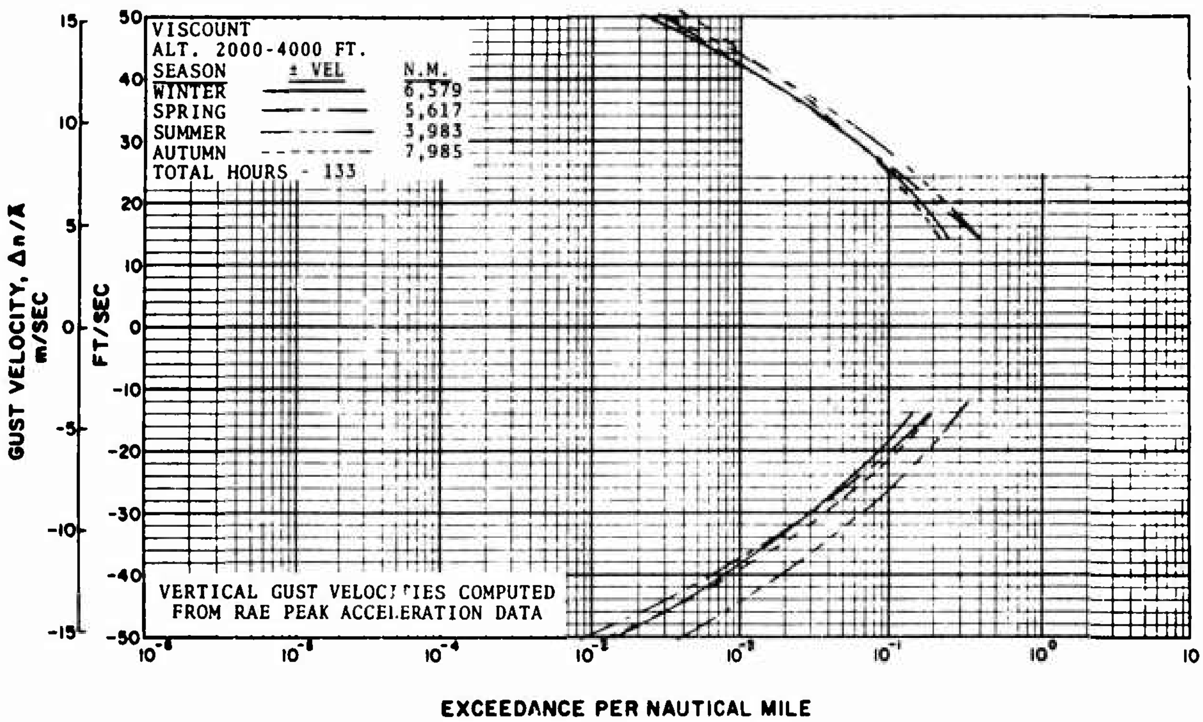

BOEING 707
ALT. 18,000-22,000 FT.
SEASON ± VEL N.M.
WINTER 2,270
SPRING 8,633
SUMMER 8,438
AUTUMN 6,285
TOTAL HOURS - 66
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

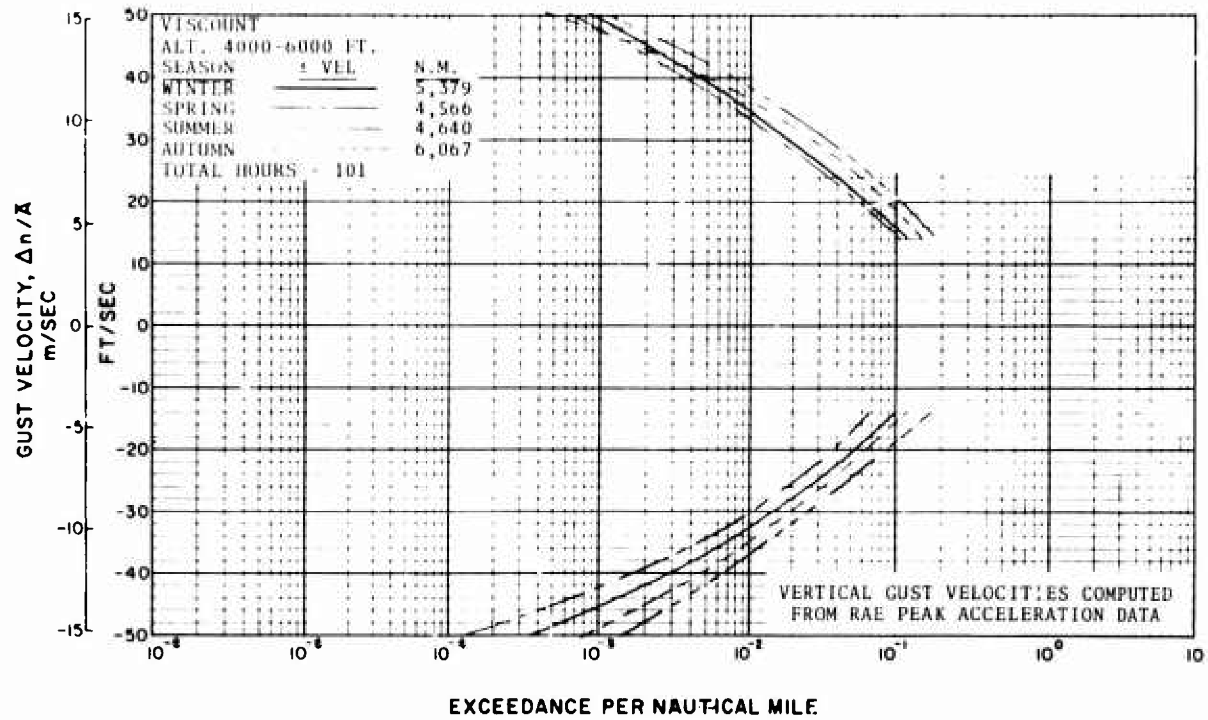

BOEING 707
ALT. 22,000-30,000 FT.
SEASON ± VEL N.M.
WINTER 11,143
SPRING 33,363
SUMMER 43,636
AUTUMN 23,123
TOTAL HOURS - 254
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

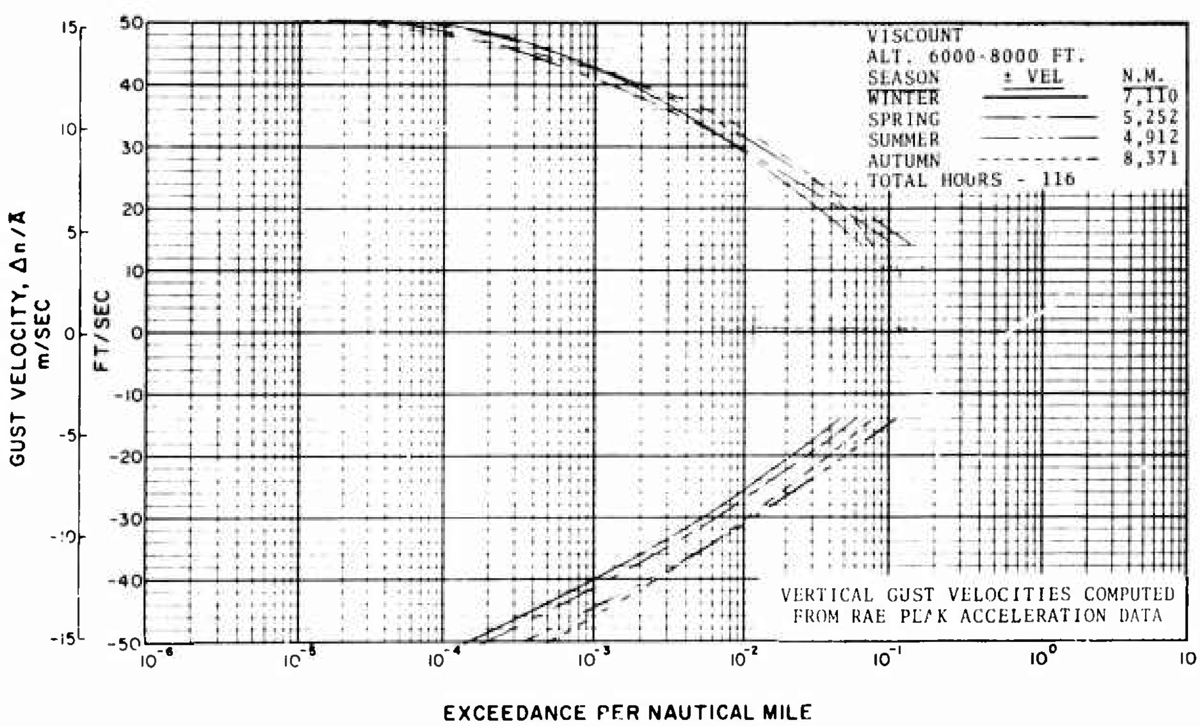

BOEING 707
ALT. 30,000-38,000 FT.
SEASON ± VEL N.M.
WINTER 60,092
SPRING 258,648
SUMMER 209,561
AUTUMN 171,796
TOTAL HOURS - 1487
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

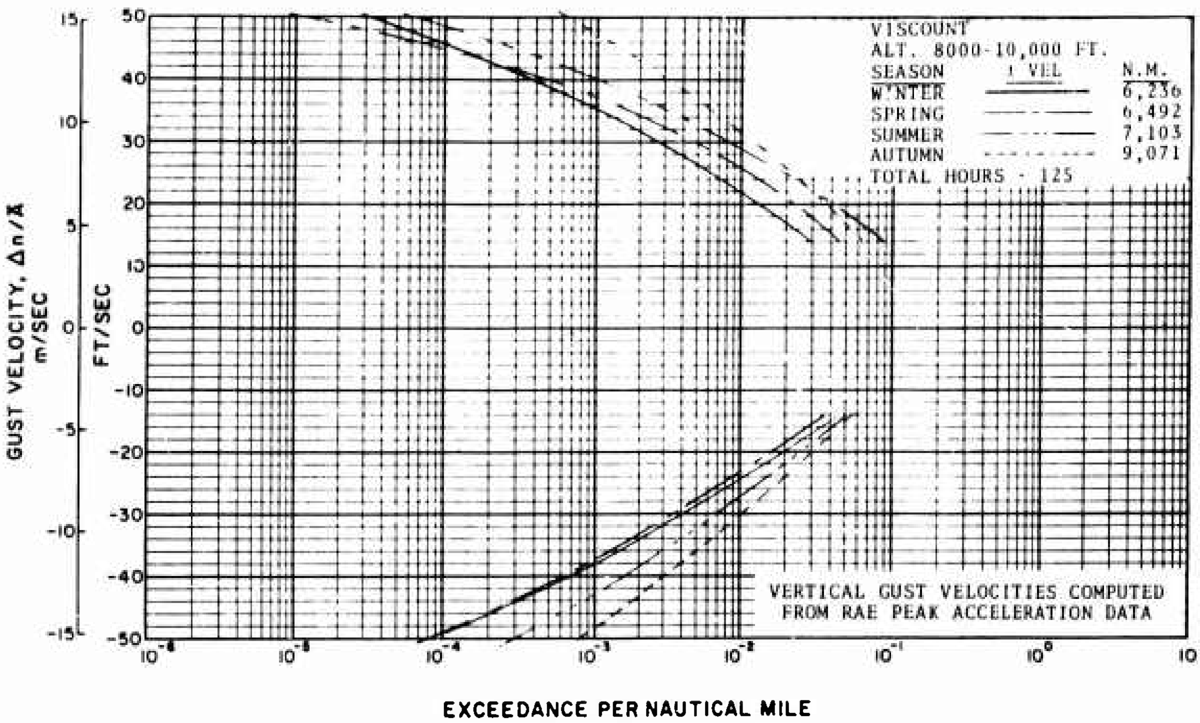

BOEING 707
ALT. ABOVE 38,000 FT.
SEASON ± VEL N.M.
WINTER 7,501
SPRING 17,662
SUMMER 18,781
AUTUMN 10,641
TOTAL HOURS - 115
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


VISCOUNT
ALT. 0-2000 FT.
SEASON ± VEL N.M.
WINTER 3,319
SPRING 3,383
SUMMER 1,673
AUTUMN 4,182
TOTAL HOURS - 77
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

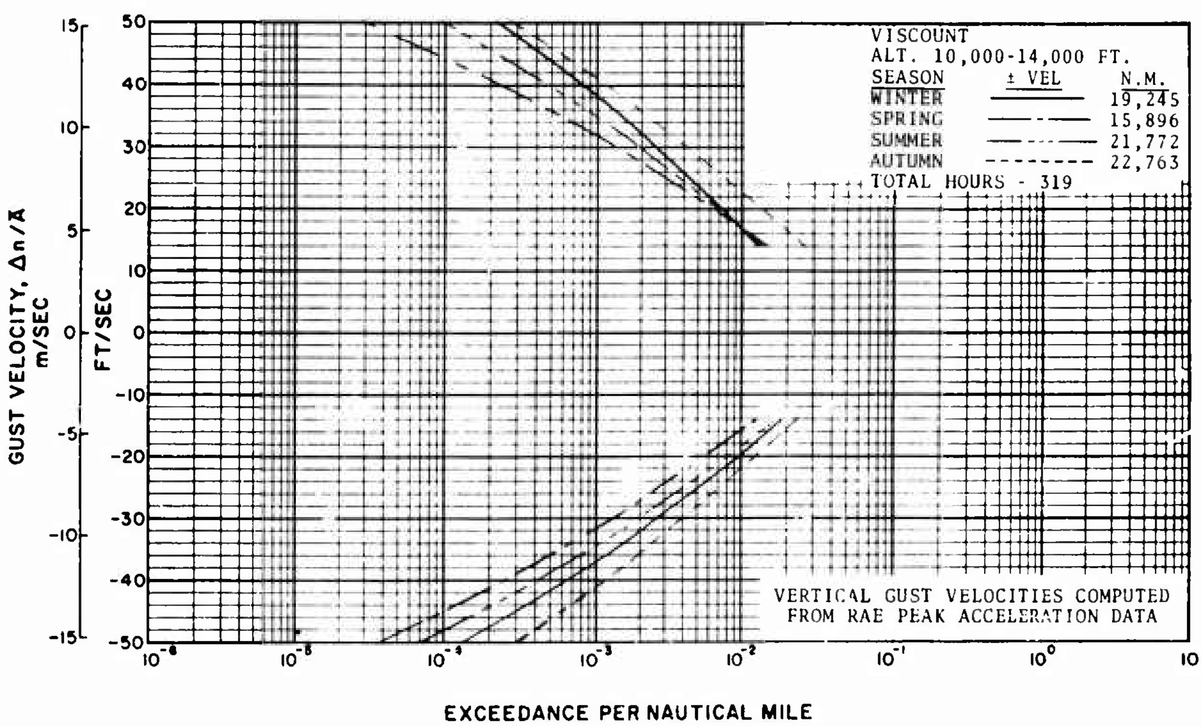

VISCOUNT
ALT. 2000-4000 FT.
SEASON ± VEL N.M.
WINTER 6,579
SPRING 5,617
SUMMER 3,983
AUTUMN 7,985
TOTAL HOURS - 133
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


VISCOUNT
ALT. 4000-6000 FT.
SEASON ± VEL N.M.
WINTER 5,379
SPRING 4,566
SUMMER 4,640
AUTUMN 6,067
TOTAL HOURS - 101
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

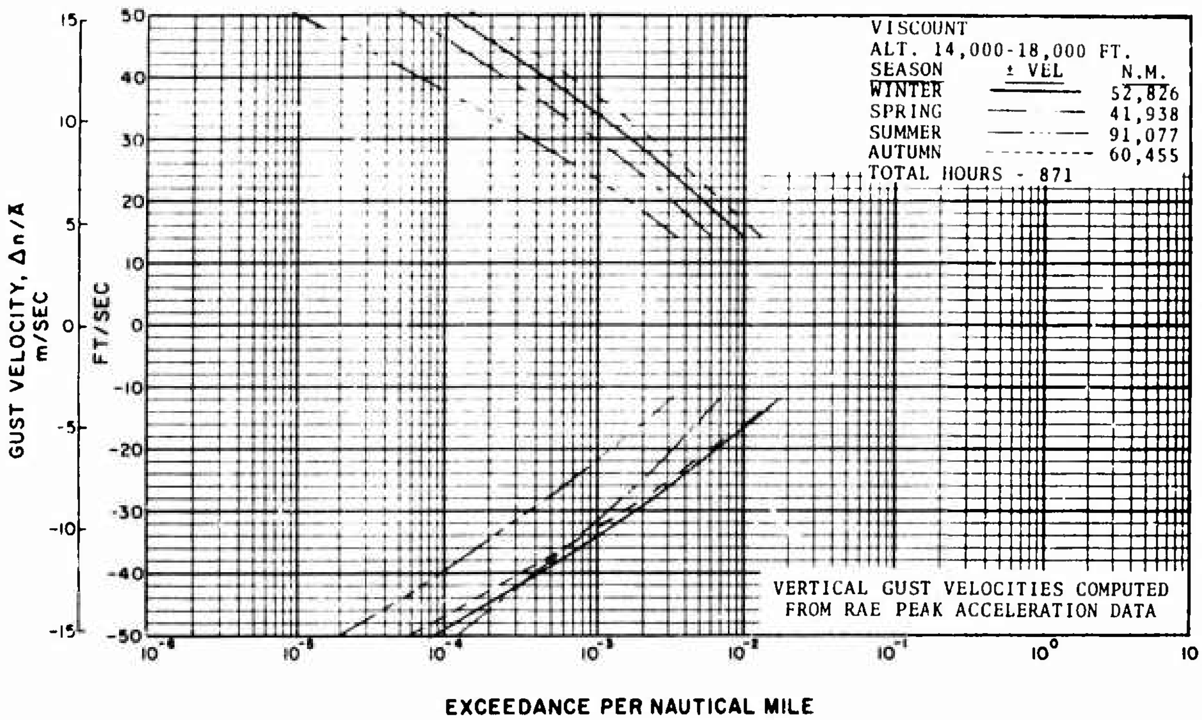

VISCOUNT
ALT. 6000-8000 FT.
SEASON ± VEL N.M.
WINTER 7,110
SPRING 5,252
SUMMER 4,912
AUTUMN 8,371
TOTAL HOURS - 116
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

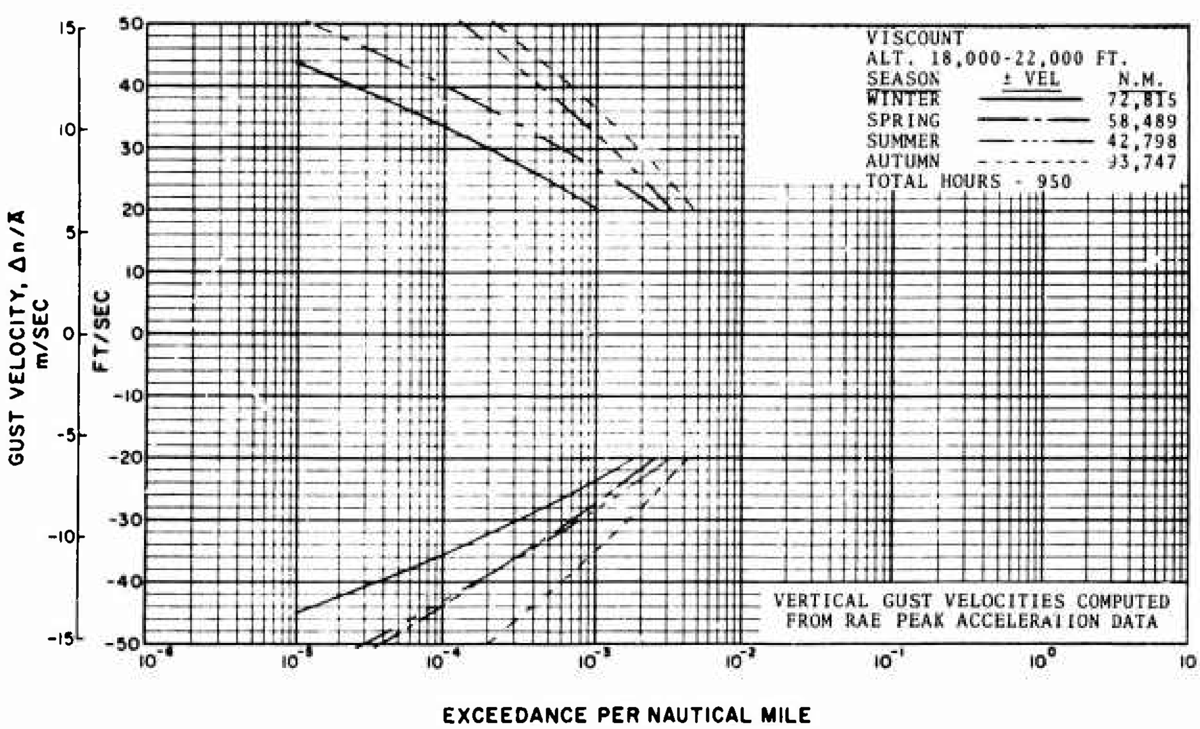


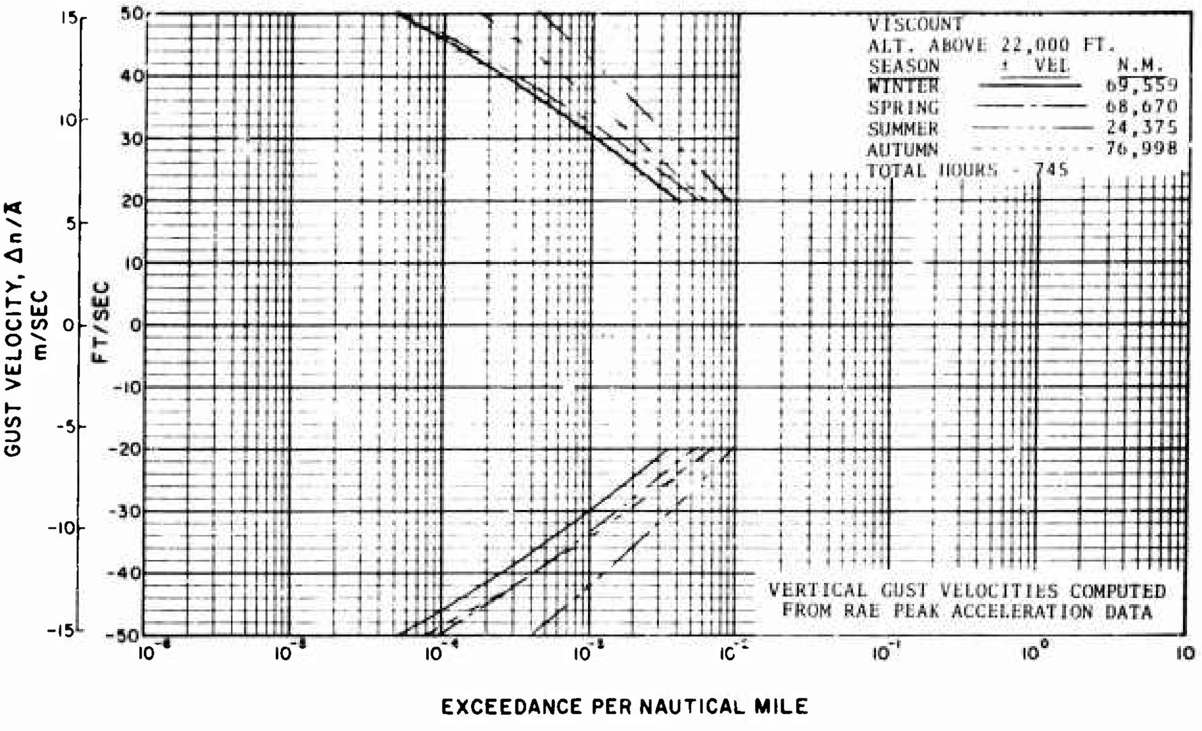
VISCOUNT
ALT. 8000-10,000 FT.
SEASON ± VEL N.M.
WINTER 6,236
SPRING 6,492
SUMMER 7,103
AUTUMN 9,071
TOTAL HOURS - 125
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE



VISCOUNT
ALT. 10,000-14,000 FT.
SEASON ± VEL N.M.
WINTER 19,245
SPRING 15,896
SUMMER 21,772
AUTUMN 22,763
TOTAL HOURS - 319
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


VISCOUNT
ALT. 14,000-18,000 FT.
SEASON ± VEL N.M.
WINTER 52,826
SPRING 41,938
SUMMER 91,077
AUTUMN 60,455
TOTAL HOURS - 871
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


VISCOUNT
ALT. 18,000-22,000 FT.
SEASON ± VEL N.M.
WINTER 72,815
SPRING 58,489
SUMMER 42,798
AUTUMN 93,747
TOTAL HOURS - 950
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/A m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE


VISCOUNT
ALT. ABOVE 22,000 FT.
SEASON ± VEL N.M.
WINTER 69,559
SPRING 68,670
SUMMER 24,375
AUTUMN 76,998
TOTAL HOURS - 745
VERTICAL GUST VELOCITIES COMPUTED FROM RAE PEAK ACCELERATION DATA
GUST VELOCITY, Δn/Ā m/SEC
FT/SEC
EXCEEDANCE PER NAUTICAL MILE

ACKNOWLEDGMENT

This task could not have been completed without the help of the experts named in this report. Their responses and contributions were timely and encouraging. In addition, the following should be cited for special acknowledgment: A. C. Larsen, Boeing-Seattle; John Dempster, Boeing-Wichita; John Firebaugh, Lockheed Georgia; John Bell and Roger Osborne, Oklahoma City Air Materiel Area; W. O. Martin, Warner Robins Air Materiel Area; Col. Charles K. Grimes, Air Force Flight Dynamics Laboratory; William Austin and William Miller, Air Force Aeronautical Systems Division: Paul Hunter and Thomas Coleman, NASA-Langley; Demetrius Zonars and Robert Hurd, Aeronautical Systems Division's computer center, who provided the computer time and scheduling to meet our deadline; and a host of unknown people whose letters and telephone calls were very productive. To these and to my colleagues at Technology Incorporated, Joseph Giessler and Jeannine Hilt, I am most grateful.

REFERENCES

1. Peckham, C. G. — Flight-Measured Turbulence in the NATO Nations. AGARD Report 555, February 1967.

2. Press, H.; Meadows, M. T.; Hadlock, I. — A Reevaluation of Data on Atmospheric Turbulence and Airplane Gust Loads for Application in Spectral Calculations. NACA Report No. 1272.

3. Liepmann, H. W. — On the Application of Statistical Concepts to the Buffeting Problem. Jour Aero Sci, Volume 19, No. 12, December 1952.

4. Fung, Y. C. — Statistical Aspects of Dynamic Loads. Jour Aero Sci, Volume 20, No. 5, May 1953.

5. Press, H.; Mazelsky, B. — A Study of the Application of Power Spectral Methods of Generalized Harmonic Analysis to Gust Loads on Airplanes. NACA Report 1172, 1954.

6. Clementson, G. C. — An Investigation of the Power Spectral Density of Atmospheric Turbulence. Ph.D. Thesis, M.I.T., 1950.

7. Press, H.; Houbolt, J. C. — Some Applications of Generalized Harmonic Analysis to Gust Loads on Airplanes. Jour Aero Sci, Volume 22, No. 1, January 1955.

8. Diederich, F. W. — The Dynamic Response of a Large Airplane to Continuous Random Atmospheric Disturbances. Preprint No. 548, SMF Fund Paper, Inst Aero Sci, January 1955.

9. Chilton, R. G. — Some Measurements of Atmospheric Turbulence Obtained from Flow Direction Vanes Mounted on an Airplane. NACA TN 3313, 1954.

10. Gault, J. D. — Summary of Results from Phases I and II of Lo-Locat. Meeting on Aircraft Response to Turbulence, September 1968.

11. Taylor, J. — A Turbulence Model for Aircraft Loads. NASA-Langley Meeting on Aircraft Response to Turbulence, Compilation of Papers, September 1968.

12. Taylor J. — Manual on Aircraft Loads. AGARDograph 83, Pergamon Press, 1965.

13. Hoblit, F. M.; Paul, N.; Sheldon, J. D.; Ashford, F. E. — Development of a Power-Spectral Gust Design Procedure for Civil Aircraft. Lockheed-Burbank for the FAA, Report No. FAA-ADS-53.

14. Rice, S. O. — The Mathematical Analysis of Random Noise. Bell System Tech Journal, Volumes 23 and 24, Reprinted in Noise and Stochastic Processes, Dover, New York, 1954.

15. Houbolt, J. C. — The Art of Determining Gust Frequency Response Functions. Paper presented at the 31st AGARD Structures and Materials Panel Meeting, Tønsberg, Norway, November 1970.

16. Buxbaum, O.
Svenson, O.
Extreme Value Analysis of Flight Load Measurements. Paper presented at the 5th ICAF Sumposium at Melbourne, Australia, May 1967. Published in "Aircraft Fatigue-Design, Operational and Economic Aspects" Ed by Mann, J. Y. and Milligan, J. S., Pergamon Press, 1970.

17. Buxbaum, O.
Gassner, E.
Häufigkeitsverteilungen als Bestandteil der Lastannahmen für Verkehrsflugzeuge. Luftfahrttechnik-Raumfahrt-Technik, BD. 13 (1967) in English: RAE-Library Translation No. 1303, June 1968.

18. Buxbaum, O.
Extreme Value Analysis and Its Application to C.G. Vertical Accelerations Measured on Transport Airplanes of the C-130 Type. AGARD Report No. 579, March 1971.

19. Clay L.
Berens, A.
Structural Flight Loads Data from C-130 Aircraft. Report No. ASD-TDR-64-78, WPAFB, Ohio, USA, March 1964.

20. Bullen, N. I.
A Review of Counting Accelerometer Data on Aircraft Gust Loads. Report No. CP No 933, Ministry of Technology, United Kingdom, 1967.

21. Sewell, R. T.
Analysis of VGH Records from Yukon Aircraft. Final Report, National Research Council of Canada, LR-484, July 1967.

22. Richardson, N. K.
NACA VGH Recorder. Technical Note 2265, February 1951.

23. Svenson, O.
Buxbaum, O.
Betriebsanleitung für den LBF-Filmoszillograph. (Operating Instructions for the LBF Film Oscillograph) LBF Report No. 6144, 1964.

24. Lumley, J. L.
Panofsky, H. A.
The Structure of Atmospheric Turbulence. Interscience Monographs and Texts in Physics and Astronomy, Volume III, Wiley, New York, 1964.

25. Dryden, H. L.
A Review of the Statistical Theory of Turbulence. Turbulence Classic Papers on Statistical Theory, Interstate Publishers Inc., New York, 1961.

26. Lindberg, G. M.
The Use of Power Spectral Density Methods in the Analysis of Aircraft Response to Gusts. Internal Report of the Structures and Materials Laboratory, National Research Council of Canada, Ottawa, December 1967.

27. Austin, W. H.
Environmental Considerations in the Structural Design of a Low Level Strike Aircraft. Paper Delivered at an AGARD Inter-panel Meeting, Paris, France, October 1964.

28. Houbolt, J. C.
Steiner, R.
Pratt, K. G.
Dynamic Response of Airplanes to Atmospheric Turbulence Including Flight Data of Input and Response. NASA TR R-199, June 1964.

29. Houbolt, J. C.
Gust Design Procedures Based on Power Spectral Techniques. Technical Report AFFDL-TR-67-14, August 1967.

30. Houbolt, J. C.
Design Manual for Vertical Gusts Based on Power Spectral Techniques. AFSC Report AFFDL-TR-70-106, December 1970.

31. Von Karman, T.
Progress in the Statistical Theory of Turbulence. Turbulence Classic Papers on Statistical Theory, Interstate Publishers, Inc., New York, 1961.

32. Burns, A.
Power Spectra of the Vertical Component of Atmospheric Turbulence Obtained from Concurrent Measurements on an Aircraft and at Fixed Points. Ministry of Aviation, U.K., C.P. No. 689.

33. Burns, A.
Power Spectra of Low Level Atmospheric Turbulence Measured from an Aircraft. Ministry of Aviation, U.K., C.P. No 733.

APPENDIX A

RECORDING SYSTEMS

The bulk of the VGH data collected were recorded either on the RAE recorder or on an oscillograph system. However, brief descriptions of all recorders used, the methods of processing the data, and the means of separating the turbulence are given. More extensive treatments are readily available in References 19 to 23.

U.S. Air Force System

The oscillograph system recorded each parameter as a trace on a photosensitive paper; the amplitude was modified by the rotation of a mirror called a galvanometer, the rotation being proportional to the amplitude. Airspeed and altitude are recorded as differential and static pressure sensed from the aircraft pitot system. The vertical acceleration was sensed at (or near) the aircraft center of gravity by a bonded strain gage type of accelerometer whose range was determined by the aircraft type. For large aircraft of the bomber or cargo type, this range was ±5g and, for fighter type aircraft, -3g to 12g. The galvanometer had a natural frequency of 100 Hz with a damping ratio of 0.9. The accelerometer had a natural frequency of 15 Hz and a damping of 0.7 of critical damping. No other electrical filtering was used in the measuring of the normal acceleration. Using standard accelerometer response curves to sinusoidal acceleration, the accelerometer was flat to approximately 4.5 Hz and down 3db at approximately 11 Hz and then a roll-off at 12db per octave.

Accelerations were read at the maximum excursion between successive crossings of the 1.0g line. Only readings greater than an increase (or decrease) of 0.1g were read. Each individual reading was identified as being caused by turbulence or maneuver. The criteria for turbulence cause was:

1. A rough or jagged airspeed trace.
2. A rough acceleration with sharp irregular peaks.
3. A rapid rise and exponential decay of the peaks.
4. Short peak duration, generally 2 to 4 seconds or less.

Along with acceleration the corresponding airspeed and altitude values were read, but these values were also read often enough to give a time history of both parameters.

During the processing run which calibrated airspeed, altitude, and acceleration into the desired units, weight was calculated and associated with the coincident values of airspeed and altitude. The weight calculation accounted for fuel usage, cargo, and store drops.

NASA VGH Recorder

Each element in the recorder employed a tilting mirror and lens arranged to focus the image of a straight-filament source lamp on the moving record paper.

Two cells containing pressure-sensitive diaphragms were connected to the airplane pitot-static lines to measure airspeed and altitude. The diaphragms deflected in proportion to the impressed pressures and their motions were magnified and transmitted to the record paper by the tilting mirror in each cell. Also in each cell was a fixed mirror for providing reference lines on the record.

The acceleration transmitter employed wire strain gages mounted on a cantilever beam. These gages were wired in the form of a Wheatstone bridge, the output voltage of which was proportional to the impressed acceleration. The beam was mounted in a sealed case filled with silicone oil which served as the damping medium and also protected the gages from moisture. A natural frequency of about 22 cycles per second was considered low enough to isolate it from engine vibrations but high enough to reproduce faithfully the gust accelerations normally encountered. A 25-watt heater and thermoswitch were built into the transmitter to maintain it at constant temperature. The galvanometer natural frequency was about 8 cycles per second and its damping was set at about 0.7 critical. The response of the combination was flat within about 1% up to an impressed sinusoidal frequency of 4.5 cycles.

In the processing, only peak values between crossings of the 1.0g line were measured, along with the coincident values of airspeed and altitude, and subjectively classified as maneuvers or turbulence. The data were also segmented by flight condition, i.e. ascent, descent, cruise. The data were preserved as Δn by airspeed, Δn by altitude, Δn by record, average true airspeed, and distance traveled for each 5000-foot altitude band.

The recorder was most generally used to monitor commercial flights.

APPENDIX B

SOURCE OF DATA BY COUNTRY

A set of magnetic tapes and a summary data report have been sent to the following persons:

Canada	Richard T. Sewell Structures and Materials Laboratory National Research Council Ottawa 7 Ontario Canada
France	Gabriel Coupry O.N.E.R.A. 29-39 Avenue de la Division Leclerc Chatillon-sous-Bagneux Seine, France
Germany	Otto K. Buxbaum Laboratorium für Betriebsfestigkeit 61 Darmstadt-Eberstadt Muhltalstrabe 55-57, Germany
Italy	
The Netherlands	J. B. DeJonge National Aerospace Laboratory NLR Voorsterweg 31 Emmeloord, The Netherlands
United Kingdom	Norman I. Bullen Ministry of Aviation Structures Department Royal Aircraft Establishment Farnborough, Hants United Kingdom
United States	Clem J. Schmid Design Criteria Branch Aeronautical Systems Division Wright-Patterson Air Force Base, Ohio USA

APPENDIX C

TAPE DESCRIPTION

The tapes are written with odd parity in the BCD format at 800 BPI on seven-track tape.

To understand the VGH tape data, a detailed description of the data as they are filed is given. A word is defined as six characters (numbers, letters, symbols) or 36 binary bits. The data are written in block sizes of 432 words, each containing four records of 108 words. A block is a convenient portion or set of data, which may be further divided into subsets or records. Masses of data are thus processed by processing individual blocks. The historical record takes up the first two blocks and is, therefore, limited in size. In addition to defining the type of aircraft, the source of the data, and the units used, the record also defines all parameters or constraints and the intervals used to record these parameters.

All succeeding blocks of data for an aircraft type contain four identical records of 108 words each. The first ten words define aircraft type, model, flap position, season, gross weight, altitude, equivalent airspeed, flight condition or segment, and fuel weight. These items are represented by codes or numbers whose meaning is given to the historical record. In addition to this identification, these ten words contain the total number of hours (to four decimal places) represented by the data and the distance traveled in nautical miles (to two decimal places). The next 18 words contain the original acceleration frequencies presented in twenty intervals of incremental acceleration (Δn) - ten positive and a symmetrical 10 negative. The field sizes (maximum frequency) range from three to seven digits. The next 40 words represent the Δn intervals converted to 20 intervals of gust velocity ($\Delta n/A$) of either 5 feet/second or 2 meters/second versus cumulative frequency of occurrence.

The next 40 words contain the modified frequencies, i.e., frequencies multiplied by the characteristic frequency of the input (Von Karman spectrum of turbulence) and divided by the characteristic frequency of the output (aircraft acceleration), of the gust velocity. These frequencies are modified cumulative distributions and must be divided by the number of nautical miles to obtain frequency per mile. Sets of data can be readily combined if the division is not made. The division is performed prior to printing the data.

The data in the last two records are carried in floating point, i.e., as an integer multiplied by ten to a power, to maintain the maximum number of significant non-zero digits.